Study Report 2002-03

Proposed New Army Aptitude Area Composites
A Summary of Research Results

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The Army currently employs nine Aptitude Area (AA) composites to classify new recruits; they are derived from the Armed Services Vocational Aptitude Battery (ASVAB) subtests in a manner that makes them easy to calculate but inefficient for classification. At the end of 2001 the Office of the Secretary of Defense (OSD) will eliminate the two timed subtests in the ASVAB . This will reduce the classification efficiency of the existing Army composites and necessitate redefinition of the existing composites. In their place the Army is considering for adoption new composites that have been developed by ARI based on a job performance criterion. ARI has developed a set of 17 operational classification-efficient job families and corresponding composites that would be used for administrative, counseling, and school proponent purposes. The new structure strongly resembles the existing structure, in effect being a further shredding of existing families. The new composites / job families are undergoing further testing and evaluation, and will be considered for implementation in the 2004 - 2005 period. In the meantime ARI has developed an interim set of composites that retain the existing nine operational job families but are also based on defensible job performance data. These will be implemented January 2002 while planning for the new 17 Army Aptitude Area composites goes forward.

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FOREWORD

This report summarizes development of new Army aptitude area (AA) composites at the Selection and Assignment Research Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences over the 1995 – 2000 period. This work is one strand of a larger effort to improve classification (i.e., determination of most appropriate initial training and subsequent job assignment) of new recruits entering the Army, and has been conducted with the sponsorship of the Enlisted Accessions Division of the Directorate of Military Personnel Management of the Office of the Deputy Chief of Staff for Personnel.

The AA composites are derived from the Armed Services Vocational Aptitude Battery (ASVAB) given to all applicants, and play a central role in defining and measuring recruit aptitudes required for training and assignment into Army jobs. The report first describes development of 17 new composites and job families, designed to be more classification-efficient than the existing nine AA composites. The new 17 composites are being evaluated and tested at the present time, and are under consideration for implementation in the 2004 – 2005 period. The report then describes the development of a set of nine interim composites scheduled to replace the existing nine composites in January 2002. The immediate catalyst for the development and implementation of the interim composites has been the DOD decision to eliminate two subtests within the ASVAB, thereby creating a need to reconfigure the composites. Like the proposed new 17 composites, the interim composites are based on measures of soldier job performance and use all the information contained in the ASVAB.

The interim composites were in fact implemented on January 2, 2002. Prior to the implementation decision, briefings and discussions were held with the responsible Army managers within Total Army Personnel Command, Office of the Deputy Chief of Staff for Personnel, and the Army Development Systems XXI Task Force.

ZITA M. SIMUTIS
Technical Director

EXECUTIVE SUMMARY

The Army currently employs nine Aptitude Area (AA) composites to classify new recruits; they are derived from the Armed Services Vocational Aptitude Battery (ASVAB) subtests in a manner which makes them easy to calculate but inefficient for classification. The Office of the Secretary of Defense (OSD) is eliminating the two timed subtests in the ASVAB by December 31, 2001. This is due to the expenses involved in administering these tests in an automated environment. When this comes to pass, the classification efficiency of the existing Army composites will be further reduced and will necessitate measures to redefine the existing composites. In their place the Army is expected to adopt new composites, which have been developed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) based on a job performance criterion.

The Army's current set of nine composites were formed in 1976 to represent measures of the aptitudes / skills required for training and assignment to the corresponding nine Army job families. Classification efficiency requires the use of composites that can distinguish how well a recruit is likely to perform in different jobs. The AA composites have limited ability to do this. In addition, the AA composites were not developed with an on-the-job performance criterion. The training criteria used to validate the AA composites were the best available criteria at the time, but do not fully represent soldier job performance. Each composite is formulated as a combination of four unit-weighted subtests (except for Clerical). This approach is a carry-over from the 1950s when calculations were kept as simple as possible, reflecting earlier limitations of computing power. One consequence is that AA composites do not track performance as well as they might. A better approach is full least-squares estimation, in which all subtests contribute to each composite in proportion to their power to explain variation in performance.

Based upon extensive research utilizing job performance data, ARI has developed a set of 17 operational classification-efficient job families and corresponding composites which would be used for administrative, counseling, and school proponent purposes. Equivalent minimum eligibility standards (cutoff scores) would be established against these new composites. This job family structure is consistent with the career management fields currently used by the Army and with the current AA system. The new structure is, in effect, a further shredding of existing families.

In early 2001 the responsible Army agencies indicated that the changes in databases and procedures to effect a change to 17 job families and composites could not be accomplished in time to meet the OSD deadline. Accordingly, ARI was tasked to develop an interim set of composites that retained the existing nine operational job families and utilized the reduced ASVAB. Given the strong preference for predicted performance composites by ARI and its DCSPER sponsor, ARI estimated least-squares composites using the 1989 Skill Qualifications Test (SQT) database.

The resulting interim composites represent a predicted performance metric with strong relationships between the composites and AFQT; its application leads to compositional effects that favor qualification rates of Category 1-IIIA's relative to IIIB's and IV's. As a new metric, the interim composites require (small) changes in cutoff score levels in order to maintain the existing demographic balance in qualification rates. Because the average predicted performance of those qualifying under the interim composites is somewhat higher than under the existing composites, cutoff score levels can

be adjusted downward to preserve the demographic balance without reducing average performance levels.

PROPOSED NEW ARMY APTITUDE AREA COMPOSITES

CONTENTS

Proposed New Army Aptitude Area Composites

The Army Research Institute (ARI) has been conducting research with the objective of improving the effectiveness of Army classification (i.e., matching of recruits to initial job training assignments). Under current Army procedures, applicants are offered initial training in MOS for which they are eligible and which meet the accession needs of the Army. Eligibility is based on minimum standards, with applicants' AA (Aptitude Area) composite scores serving as the scale upon which MOS eligibility is measured. Two major recommendations have come out of the research conducted by ARI. The first recommendation is to improve the classification process. The existing training reservation system (known as *REQUEST*) should be enhanced so that recruits are assigned to jobs that they are likely to perform best, while meeting the training management goals of the Army. The Enlisted Personnel Allocation System enhancement, now under development, is designed to push *REQUEST* toward optimized assignments. The second recommendation is to improve the classification metric by replacing the AA composites with more precise measures of predicted performance. We have found that the AA composites were not adequately designed for today's classification task of distinguishing recruit predicted performance across a variety of jobs.

In this report we summarize the development of new classification-efficient composites and corresponding job families.

<u>Role of Test Composites in Classification and Training Management</u>

In conducting classification and training management functions, the Services have created occupational aptitude test composites derived from the Armed Services Vocational Aptitude Battery (ASVAB). Each Service creates and applies its own aptitude composites in the manner that it sees fit. Generally, the composites are chosen and applied because they have been shown to predict training performance for broad classes of occupations within a Service (Eitelberg, 1988, p. 69). Thus, for purposes of classification, broad classes of occupations have become defined with respect to ASVAB composite subject areas. We will refer to these broad classes of occupations as job families.

The Army's current nine AA composites go back to 1976. These composites were formulated to represent measures of the aptitudes / skills required for training and assignment to the corresponding nine Army job families: clerical, combat, electronics repair, field artillery, general maintenance, mechanical maintenance, operators / food, surveillance / communications, and skilled technical. Table 1 depicts the AA composites and their component ASVAB subtests. Eligibility for training in a particular MOS is determined by the recruit's AA composite score relative to the minimum or cutoff score required for training in that MOS. For example, MOS 55B (ammunitions specialist) requires a minimum score of 95 on the General Maintenance composite to be eligible for job training and assignment.

Table 1: ASVAB Subtests Comprising the Army's AA Composites and AFQT

	ASVAB SUBTESTS								
	AR	MK	VE	AS	EI	GS	MC	CS	NO
AA COMPOSITES									
Electronics Repair	X	X			X	X			
General Maintenance		X		X	X	X			
Mechanical Maintenance				X	X		X		X
Operators / Food			X	X			X		X
Surveillance / Communications	X		X	X			X		
Combat	X			X			X	X	
Field Artillery	X	X					X	X	
Skilled Technical		X	X			X	X		
Clerical	X	X	X						
General Technical	X		X						
AFQT	X	X	XX						

ASVAB is comprised of following subtests: Arithmetic Reasoning (AR), Math Knowledge (MK), Verbal (VE) = Paragraph Comprehension (PC) + Word Knowledge (WK), Auto & Shop Information (AS), Electronics Information (EI), General Science (GS), Mechanical Comprehension (MC), Coding Speed (CS), Numerical Operations (NO).

The classification task is the assignment of recruits into initial job training in order to provide the best match or fit while meeting accession and training management goals. While the formulation of the AA composites as shown in the table has a certain intuitive appeal, it does not provide the requisite classification capability.

Fit pertains to congruence between recruit aptitudes and job requirements, and should be measured with predicted performance in the assigned job as the criterion. The AA composites were not developed with a job performance criterion. The training criteria used to validate the AA composites were the best available criteria at the time, but do not adequately represent soldier performance.[1] Moreover, each composite is formulated as a combination of 4 unit-weighted subtests (except for Clerical). This approach is a carry-over from the 1950s when calculations were kept as simple as possible, reflecting earlier limitations of computing power. One consequence is that AA composites do not track performance as well as they might.[2] A better approach is full least-squares estimation, in which all subtests contribute to each composite in proportion to their power to explain the variation in performance.

Classification efficiency requires the use of predictors that can distinguish how well a recruit is likely to perform in different jobs. The AA composites have limited ability to do this. Consider that

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[1] In the mid-1980s representative MOS were examined in a validation of the AA composites using school grades, early Skill Qualification Test (SQT) performance data, and Project A criterion measures, though the unit-weighted calculation procedures were retained (see Campbell (1989)).

[2] Predictive validity estimates in the literature reveal correlations in the 0.55 to 0.60 range between the composites and measures of training and job performance.

five pairs (out of 36 possible pairs) of AA composites have three out of four ASVAB subtests in common. See Table 1: these are electronics repair and general maintenance; operators / food and surveillance / communication; operators / food and mechanical maintenance; surveillance / communication and combat; field artillery and combat. And 19 pairs of AA composites have two out of four ASVAB subtests in common. The consequence is difficulty in distinguishing predicted recruit performance across these pairs of job families.[3]

<u>Developing Classification-Efficient Composites and Job Families</u>

The ASVAB subtests, which underlie the AA composites, do better in tracking job performance. Indeed, ARI Project A research of the 1980's found a relatively strong relationship between ASVAB factors and first-term soldier performance measures and validated the use of ASVAB as a selection tool.[4] The AFQT composite is used for selection into the services.

With the success of the ASVAB factors in tracking performance, ARI conducted research beginning in the early 1990's to develop classification-efficient composites for use in Army classification -- that is, to develop better measures for distinguishing recruit capabilities to do different jobs and to test the efficacy of these measures for making better classification decisions. This research was founded upon differential assignment theory (DAT), enhanced and applied by Dr. Joseph Zeidner and Mr. Cecil Johnson of George Washington University.[5]

This research has grown out of the ongoing debate among psychologists about the nature of intelligence and how it is measured. Generalizability theory suggests that one general ability factor is sufficient to predict performance on jobs with a strong cognitive component. Proponents of the theory believe that the underlying general ability factor is the only stable predictor of job performance as measured in independent samples. If it is true that specific aptitudes do not add to the prediction of job performance, then more efficient classification of individuals to jobs based on specific aptitudes is not achievable. However, if there are two or more common or unique factors that differentially predict performance in various jobs, then classification efficiency is a relevant issue (Zeidner and Johnson, 1993, p.377).

In developing DAT the research team members postulate that several factors differentially predict performance in various jobs, and argue that DAT provides a more coherent framework for job classification, although recognizing the general ability factor as the dominant predictor of performance in a selection model (Zeidner and Johnson, 1993, p.378). The empirical implementation of DAT has shown that there are useful factors contributing a nontrivial amount of classification efficiency in addition to that contributed by the general ability factor. This includes both the three common factors

[3] Additional evidence for the absence of differential classification power can be seen by examining, for each composite or job family, how many times other composites do as well or better than its own composite in explaining performance. The counts are as follows: CL, 7; SC, 7; FA, 5; EL, 4; GM, 4; MM, 3; OF, 3; CO, 2; and ST, 0. For example, at one extreme, 7 of the 9 composites do as good or better at explaining CL performance than does the CL composite itself. Validity data source: McLaughlin, Rossmeissl, et al (1984). Note that data refer to CL and SC validities before they were revised in 1984.

[4] Four ASVAB factors were derived using factor analysis: verbal, quantitative, technical knowledge, and perceptual speed. This is summarized in Zook (1996).

[5] Zeidner and Johnson have built on the earlier work by Brogden (1946, 1959) and Horst (1954).

and several of the unique factors found in the ASVAB. The empirical implementation is based upon the following three principles:

- One: New composites should utilize defensible criterion data (i.e., soldier performance data) and all the informational power of the ASVAB battery.

In the estimation and testing of new composites, the research team created and validated a job performance database of 260,000 Skill Qualification Test (SQT) observations over the 1987-89 period. A carefully developed composite of hands-on and written job sample tests, known as the Project A job-specific technical proficiency measure, was used to validate the SQT criterion. The researchers found relationships between ASVAB and SQT similar to those found between ASVAB and Project A measures, providing additional confidence in reliance upon ASVAB in the development of the new composites (Zeidner, Johnson, Vladimirsky, 1997).

For each job family, new composites were developed by estimating the functional relationship between individual SQT performance and ASVAB subtest scores -- hence the name predicted performance composites. The resulting composites have good predictive power or what psychologists call predictive validity, and all subtests contribute to each composite, but not equally. In other words, the new composites utilize weights that allow each subtest to make its maximum contribution (taking into account the other subtests in the battery) to predicted performance. This is in marked contrast to the use of unit weights in the existing composites, in which the contributions of selected subtests are predetermined and set equal to each other without regard to explanatory power.

- Two: Classification efficiency not only depends upon (a) how well the composites predict performance but how distinctive the composites are, one from another, and also (b) how many distinct job families can be identified using available criterion data.[6] In other words, predictive validity is only one term in the classification efficiency equation and, thus, classification efficiency cannot be described adequately by predictive validity alone.

According to this formulation, predictive validity and the distinctiveness of the composites (as described by their intercorrelations) are both affected by increasing the number of job families. Increasing the number of job families affects validity because it results in more homogeneous jobs being placed together to be predicted by a single composite. Increasing the number of job families reduces the intercorrelations among the composites because it results in a greater uniqueness in the job families. And finally, as the number of job families increases, it is possible to more precisely assign individuals to job families by capitalizing on intra-individual differences. Using the SQT database and a clustering algorithm designed to identify classification-efficient job families, two sets of classification-efficient job families were identified – a detailed set of 150 and a summary set of 17 job families.[7]

[6] See Brogden (1959); Johnson, Zeidner, and Leaman (1992, p. 6).

[7] We begin with a set of 150 job families that can be identified with the SQT data set. In this initial position, maximum classification efficiency would obtain with each MOS as its own job family. The clustering procedure entails finding the two MOS which can be combined into a single job family with the smallest loss in efficiency. This is determined with simulation experiments, and the selection of that combination which yields the largest MPP of assigned recruits. The steps are repeated until further clustering of job families is judged to reduce classification efficiency by an unacceptable amount.

We can illustrate how the new (classification-efficient) composites differ from the existing AA composites. In the earlier discussion we pointed out the difficulty of distinguishing between the existing Operators / Food and Surveillance / Communications composites because they share three ASVAB subtests in common (AS, MC, VE). However, when we look at the new composites (see Charts 1A and 1B) we see notable differences.[8] In the first place, the four top contributors in new Operators / Food are AS, AR, MC and VE; now AS, MC, and VE are the core of the existing composite, while AR has a very important role in new Operators / Food but is not part of the existing operators composite. Second, the four top contributors in Surveillance / Communications are MK, VE, AR, and EI; only AR and VE are part of the existing composite. Indeed, MK plays a defining role in the new Surveillance / Communications composite but is not part of the existing composite.

- Three: Classification efficiency should be evaluated by measuring soldier mean predicted performance (MPP) in job assignments made within classification optimization experiments.

The simulation experiments utilize Army job performance and ASVAB data circa 1989: individuals are assigned so as to maximize predicted performance while meeting MOS quotas and certain other distributional constraints (but stopping short of the complete set of training management constraints). In these experimental simulations assignments are made on an entity-by-entity basis while avoiding the assignment of an entity to any job family or MOS for which the quotas have been filled within a batch or sub-sample. The predicted performance of each entity in his/her assigned job family is computed, and the average or mean predicted performance is computed.

The experiments were conducted using a "triple cross validation" design to assure unbiased estimates. The design requires three independent samples: (a) an analysis sample, for estimating the predicted performance function used during the assignment process; (b) cross samples which serve as the source of entities that are optimally assigned in the simulation; and (c) an evaluation sample, for estimating the predicted performance function used in the evaluation of the assignments made. Each experiment is conducted twice, with the role of analysis and evaluation samples reversed, and the results averaged.

The results of the classification simulation experiments are expressed in MPP and shown in Table 2. By comparing the 10 job family[9] new composite results (MPP = .123) with the existing AA family results (MPP = .023) we see that the new composites provide more than five times the classification power as measured by MPP.[10] In other words, improved accuracy in the estimation of predicted performance, utilizing only the existing job families, promises large gains in classification. And when 150 job families are identified, with the greater homogeneity of these families and greater overall distinction between them, the classification gains increase to more than eight times. Indeed, we estimate that the performance gains obtainable from improved classification would rival in size those obtained from existing selection-for-service.[11]

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8 This illustration is taken from a 17 job family structure proposed as the second tier and described below.

9 A very small General Technical (GT) family is included; otherwise, structure is same as existing operational families.

10 Random assignment would result in an MPP of zero.

11 That is, the performance gains due to improved classification are estimated to exceed those obtained from the screening out of low AFQT applicants. See Zeidner, Johnson, Vladimirsky, and Weldon (1997).

Chart 1A. Existing AA Composites: OF vs. SC

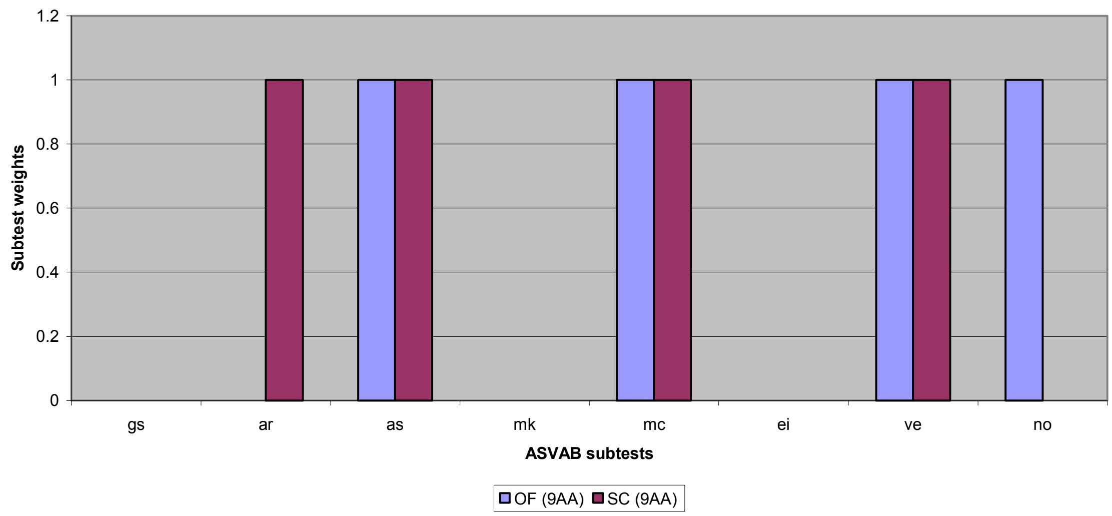
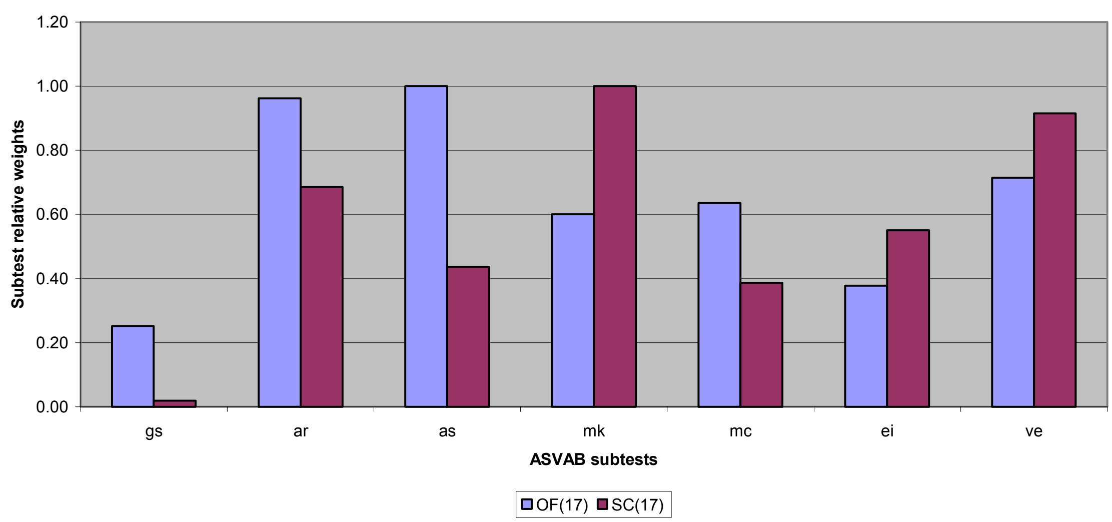


Chart 1B. New Composites: OF vs SC



The results depicted in Table 2 (with the exception of the last row) are based on a 9-subtest ASVAB battery – they precede the DoD decision to delete the Numerical Operations and Coding Speed subtests from the battery. The last row indicates the overall loss in classification efficiency from deletion of these subtests. We would expect that the MPP estimate of a 9-LSE composite based on a 7-subtest battery would be reduced in the same proportion.

In the simulation experiments described, the recruit is assumed to choose the job opportunity at the top of his/her list. In reality, classification gains are affected by the behavior of recruits choosing among an ordered-list of job training opportunities. To examine the effects of job choice behavior upon classification gains, the research team conducted an additional set of simulation experiments.[12] They compared choosing from the top-of-the-list job versus a 75% probability of choosing one of the top five jobs on the ordered list --- deemed to be a reasonable depiction of job choice behavior in an operational setting --- and found a reduction of .072 in MPP. In this case, the classification gains obtained (i.e., MPP = .121) are still more than five times those achievable using optimization procedures with the existing AA composites.[13]

Table 2: Estimated MPP – Results of Simulation Experiments

Family size	Unbiased MPP
AA – 9 operational families (unit weights)	.023
10 (LSE weights)	.123
13 (LSE weights)	.138
17 (LSE weights)	.145
150 (LSE weights)	.195
150 (LSE weights; 7 ASVAB subtests)	.183

Source: Zeidner, Johnson, Vladimirsky, and Weldon (2000a, Table 3) and (2000b, Table 3).

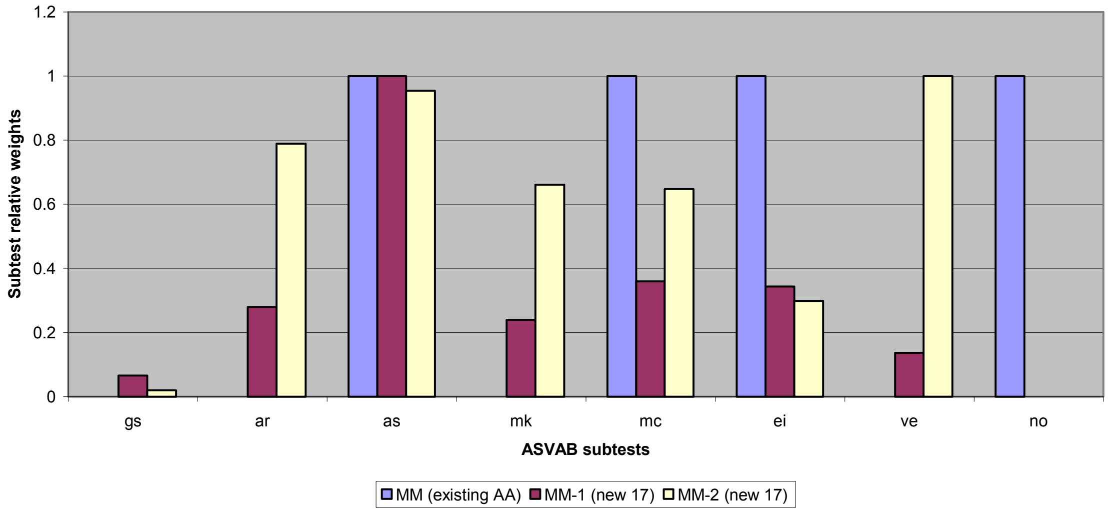
[12] These experiments are described in Johnson, Zeidner, Vladimirsky, and Weldon (1999).

[13] The monetary value of these classification gains can be estimated as (what economists call) the opportunity cost of retaining the current AA system. In the present context of an optimizing assignment procedure, this is the additional cost of using current AA composites to achieve the same level of performance gains obtainable using the new composites. Specifically, using current AA composites, how many additional 1-3A recruits, in place of 3B recruits, would be required to achieve the same gains obtained using the new composites, and what would it cost to acquire them?

The heart of the opportunity cost calculation is determination of the number of additional 1-3A recruits required. Using the 1997 accession cohort as a baseline, the assignments made using the current procedures are ordered from high to low by AFQT score. For individuals at each percentile score, average and cumulative average predicted performance scores for the job assignments actually made are calculated. To meet a predetermined overall average performance target, individuals from the bottom are successively deleted and replaced with 1-3A recruits (assumed to score at the original 1-3A average) until the performance target is reached. We find that that the percentage of 1-3A recruits would have to rise 10 - 15 percentage points and would conservatively cost in the neighborhood of $100 million in additional recruiting costs.

Calculations are made for a cohort size of 72,000, with 1-3A recruits comprising about 68%. Average recruiting costs are $11,660 for high-quality and $6,223 for low-quality recruits. Marginal costs are estimated at $35,555 for high-quality recruits, and assumed to increase with high-quality share (each one percent increase in share is associated with a one percent increase in marginal costs). For example, at 80% high-quality share, the average cost has increased to $14,935 for high-quality recruits. Recruiting costs refer to 1995 (Source: USACEAC Army Manpower Cost System).

Chart 2. Mechanical Maintenance Composite - Existing vs. New



Fairness of the New Composites

As part of the development of the new composites, the ARI research team has also examined the fairness of the new composites from a gender and race perspective (Zeidner, Johnson, Vladimirsky, 1998). Fairness is traditionally defined as the absence of under-predictions for minority groups for which discrimination potentially exists. In other words, a situation in which the predicted performance of minority group members falls below their actual performance would call into question the fairness of the prediction instrument -- in this case the test composites.

The fairness of the new vis-à-vis the existing AA composites was examined using data based on actual assignments of recruits and data from simulation experiments. The sample in both experiments used ARI's data set of ASVAB subtest and SQT scores.[14] In the actual assignments experiment, a distinct trend of under-predictions was found for females and blacks for both existing and new composites. While the prediction errors for females were statistically significant, the errors for females and blacks were too small to have practical significance. In the simulation experiments, again there was a consistent trend of under-predictions for minorities, the new vis-à-vis existing composites resulted in smaller errors, and the small under-predictions were considered of little practical consequence. In sum, the new composites are at least as fair as the existing composites.[15]

Recommended New Composites and Job Family Structure

The classification research findings suggest that new (predicted performance) composites are superior to the existing unit-weighted composites. Furthermore, adoption of new composites and corresponding job families within an enhanced *REQUEST* system holds the promise of dramatic increases in soldier performance. A two-tier structure is recommended for operational use.

A visible tier is comprised of 17 operational families, and would be used for administrative, counseling, and school proponent purposes just as the existing nine operational job families are used. (An invisible tier is described on page 9.) Minimum eligibility standards (cutoff scores) would be established against these new composites. The visible tier is consistent with the CMFs currently used by the Army in managing the entry-level job structure and is also consistent with the current AA system. No pair of MOS that are together in the current AA system fails to be together in the 17 job family system. The visible tier strongly resembles the existing structure, in effect being a further shredding of certain existing families. Four of the nine existing job families are divided into two relatively homogeneous sets of clusters, two are divided into three sets of clusters, and three remain as single clusters. Provisional MOS membership in the set of 17 job families is shown in Appendix B. Note that recently created MOS remain to be inserted into their appropriate job family set.

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14 The sample was limited to soldiers having the task-based written test, skill level 1 SQTs for 66 MOS obtained during FY 1987-89. The sample was further limited to enlistees who had taken the ASVAB in its current format. The total sample size in the first experiment was 83,000 enlistees and the size of the sample for the second experiment was a stratified random sample of 30,000 first-term enlistees drawn from the larger sample.

15 Additional research into fairness issues is underway in response to recommendations made by an expert panel convened in September 2001 to review ARI's classification research.

Table 3 provides a short occupational description of the 17 job families and highlights the major differences between the existing (see Table 1) and new composites. Generalizing for a moment, we can characterize the new composites by the addition of AR, VE, and MK. More detail is provided in Appendix A. In that appendix, the reader will find: (a) a table providing the new composite validities (i.e., multiple correlation with the underlying SQT performance criterion) along with composite inter-correlations; and (b) charts describing the new composites. Each chart depicts the

Table 3: New Composite Changes and Job Family Descriptions

Family	Occupation description	Highlights of the major changes in composition of the New Composites vis-à-vis existing composites
CL-1	CMF 71 clerical	VE, MK dominate
CL-2	Other clerical functions	Similar to existing clerical family
CO-1	Infantry	Adds MK in predominant role
CO-2	Combat engineer; armor crew	Adds MK, VE in predominant roles
EL-1	Combat equipment operator / maintainer	Adds VE, AS; relative balance
EL-2	Equipment operator	Adds VE, AS; MK predominates
EL-3	Equipment repairer	Adds VE in predominant role
FA	Cannon fire	Adds VE, AS
GM-1	Mechanic / repairer	Adds AR
GM-2	Various	Adds AR, MC
MM-1	Land vehicle mechanic / repairer	AS predominates
MM-2	Helicopter / aircraft repairer	Adds VE, AR, MK
OF	Various operators; food service	Adds AR
SC	Radar / radio transmission	Adds MK, EI
ST-1	Medical	Adds AR; relative balance
ST-2	Analyst	Adds AR; VE dominates
ST-3	Operations / various	Adds AR; relative balance

ASVAB subtests comprising the existing AA and new composites, and allows the reader to compare the subtest weighting structures across existing and new composites. As an illustration, consider the shredding of the existing mechanical maintenance (MM) job family into two new families: land vehicle (MM-1) and aircraft vehicle (MM-2) maintenance (also shown in Chart 2). The existing MM composite is defined by AS, MC, EI, and NO. The predominant contributor to MM-1 is AS, followed distantly by MC, EI, and MK. The major contributors to MM-2 are VE, AS, AR, MK, and MC. The latter shows more balance in the aptitudes identified as necessary to perform in the job family, and as a consequence female qualification rates across a range of cutoff scores are noticeably higher for MM-2 than for the existing MM composite (see Chart 2).

The predicted performance composites are shown in Table 4 for the 17 job families, each row depicting relative subtest weights.

Table 4: 17 LSE Composites -- Subtest Weights (Relative)

	gs	ar	as	mk	mc	ei	ve
1 CL1	0.000	0.000	0.000	0.985	0.095	0.022	1.000
2 CL2	0.000	1.000	0.261	0.712	0.269	0.175	0.797
3 CO1	0.259	0.401	0.658	1.000	0.532	0.262	0.398
4 CO2	0.428	0.813	0.893	1.000	0.731	0.518	0.809
5 EL1	0.056	0.842	1.000	0.808	0.507	0.720	0.997
6 EL2	0.235	0.636	0.680	1.000	0.474	0.556	0.675
7 EL3	0.102	0.675	0.206	0.479	0.213	0.239	1.000
8 FA	0.249	0.715	0.673	1.000	0.700	0.297	0.586
9 GM1	0.335	1.000	0.932	0.614	0.429	0.684	0.414
10 GM2	0.461	0.593	1.000	0.923	0.545	0.427	0.390
11 MM1	0.065	0.279	1.000	0.239	0.359	0.344	0.137
12 MM2	0.020	0.789	0.954	0.662	0.647	0.299	1.000
13 OF	0.251	0.962	1.000	0.600	0.636	0.377	0.714
14 SC	0.019	0.685	0.437	1.000	0.386	0.551	0.915
15 ST1	0.390	0.886	0.456	0.752	0.659	0.325	1.000
16 ST2	0.120	0.673	0.177	0.604	0.268	0.118	1.000
17 ST3	0.112	0.670	0.449	0.741	0.461	0.265	1.000

Predicted performance composites have also been estimated for 150 job families. These constitute the "invisible" tier, and would be embedded within the appropriate REQUEST module[16] for classification optimization. Thus, the classification gains embodied by greater delineation of job families is obtained without the (visible) accompanying administrative complexity. In sum, differential assignment theory supports the use of a larger number of job families, having more homogeneity within and greater heterogeneity between families, with stable weights producing higher MPPs. More stable families of this type produce larger mean validity and lower intercorrelations, thus providing greater optimization efficiency.

Adoption by the Army

A two-phase adoption and implementation process is envisioned. The purpose of the first phase is to educate and inform Army management about the issues, and obtain consensus and approval for implementation of the recommendation. As part of the "educate and inform" management, this phase could include a one-day workshop sponsored by DCSPER / PERSCOM, school proponent site visits, and briefings to Army management to synthesize the issues and school site findings. Issues that would be addressed at school proponents include: placement of MOS within new 17 operational job family structure; determination of how changes in composites would affect composition of MOS eligible applicant pool; and derivation of new cutoff scores under new composites / job family structure. In the second phase, the new composites and job family structure would be installed into Army recruiting and training management procedures with the coordination and assistance of the affected agencies.

[16] For example, the Enlisted Personnel Allocation System (*EPAS*) under development is designed to push REQUEST toward optimal assignments. EPAS field-testing is scheduled for FY 2001-03.

Interim Composites (beginning January 2002)

In early 2001 responsible Army agencies determined that the changes in databases and procedures to effect a change to 17 job families and composites could not be accomplished in time to meet the DOD deadline of December 31, 2001. Accordingly, ARI was tasked to develop an interim set of composites that retained the existing nine operational job families and utilized the remaining ASVAB subtests after deleting NO and CS. Given the strong preference for predicted performance composites by ARI and its DCSPER sponsor, ARI estimated least-squares composites (shown in Table 5) for the existing job families using the SQT database previously mentioned. The interim composite validities (i.e., multiple correlations with SQT scores), along with the composite inter-correlations, are shown in Appendix C. The existing and interim composites are compared in the charts in Appendix C.

Table 5: Interim AA Composites -- Subtest Weights (Relative)

	gs	ar	as	mk	mc	ei	ve
CL	0.000	1.000	0.110	0.767	0.148	0.110	0.980
CO	0.313	0.532	0.733	1.000	0.595	0.343	0.529
EL	0.151	0.818	0.754	0.890	0.469	0.598	1.000
FA	0.249	0.715	0.673	1.000	0.700	0.297	0.586
GM	0.411	0.828	1.000	0.794	0.503	0.577	0.417
MM	0.060	0.339	1.000	0.289	0.394	0.340	0.237
OF	0.251	0.962	1.000	0.600	0.636	0.377	0.714
SC	0.019	0.685	0.437	1.000	0.386	0.551	0.915
ST	0.187	0.727	0.357	0.697	0.446	0.230	1.000

With the exception of the clerical composite, the interim composites are noticeably different from the existing composites. Four groupings of the interim composites are suggested for descriptive purposes. The CL, EL, SC, and ST composites are constructed around verbal, arithmetic reasoning, and math knowledge subtests; the CO and FA composites feature math knowledge, with auto / shop information, arithmetic reasoning, and mechanical comprehension; the GM and OF composites feature auto / shop information and arithmetic reasoning; and MM features auto / shop information. Keep in mind that all subtests are used in each composite, and the contribution of two or three of the lesser-weighted subtests will equal that of one of the stronger subtests. Accordingly, the composites are more diverse than this description indicates.

The interim composites represent a predicted performance metric with (as it turns out) strong relationships between the composites and AFQT; its application leads to compositional effects that favor qualification rates of 1-IIIA's relative to IIIB's and IV's. As a new metric, the interim composites require (small) changes in cutoff score levels in order to maintain the existing demographic balance in qualification rates. Because the average predicted performance of those qualifying under the interim composites is somewhat higher than under the existing composites, cutoff score levels can be adjusted downward (when necessary) to preserve the demographic balance without reducing performance standards.

The compositional effects can be illustrated by looking at the Mechanical Maintenance composite in the neighborhood of a cutoff score of 100. Table 6 shows the percentage qualifying at the various line scores in this neighborhood under the existing and interim composite. As can be seen, the percentage qualifying (male and female) in the IIIB and IV test score categories is somewhat lower under the interim vis-à-vis the existing composite. This is addressed by lowering the cutoff score for the affected MOS; we found that the average predicted performance of the qualifying populations under the existing composite at a cutoff score of 100 and the interim composite at a cutoff score of 98 is approximately equal; thus, on performance grounds alone, a drop of two points is appropriate. The policy decision in this case to set the new cutoff score at 97 represents a decision to be inclusive and stretches slightly what can be justified by the increased performance.

Table 6. Percentage Qualifying -- Existing vs. Interim Composites
Mechanical Maintenance

MOS = 14J, 45E, 45N, 63A (M), 63D, 63E, 63G, 63N, 63S, 63Y, 67R, 67S, 68J, 88K, 88P

Line Score	Male				Female			
	All	1-3A	3B	IV	All	1-3A	3B	IV
MM								
100	**65.9**	**80.4**	**40.2**	**25**	**26.8**	**37.8**	**5.9**	**2.6**
MM-9								
100	64.3	81.4	33.8	16.2	24.4	36.2	2.0	0.6
99	66.9	83.7	37.0	18.8	27.0	39.9	2.6	0.9
98	69.4	85.8	40.5	21.5	29.9	43.9	3.4	1.2
97	71.9	87.8	44.0	24.2	33.0	48.0	4.4	1.3
96	74.3	89.6	47.5	27.3	36.1	52.2	5.7	1.5

Note: MM is the existing composite, based on 4 subtests, including NO subtest.
MM-9 is the interim composite, based on 7 subtests after deletion of NO and CS from the battery.

It is also of interest to illustrate the mitigating effect played by the interim composites on female qualification rates. Consider again the Mechanical Maintenance composite. The deletion of NO from the ASVAB directly affects the MM composite and female qualification rates for that composite. Table 7 shows percentage-qualifying rates at different line scores using the existing MM, MM_3SSS (which is the unit-weighted MM with NO excluded), and MM-9 composites. In the first stage – the four subtest versus the three subtest unit-weighted comparison, we see that qualifying rates for males and especially females are lower overall. At a cutoff score of 95, the female percentage-qualifying overall rate falls from 45.6% to 28.6% with the deletion of the NO subtest. In the second stage – the three subtest unit-weighted versus the least-squares composite, we see that percentage-qualifying rates are slightly higher for males and noticeably higher for females, indicating mitigation by the least-squares composite over the existing composite with NO deleted.

Table 7. Percentage Qualifying Rates for Mechanical Maintenance Composites

Line Score	Male All	Male 1-3A	Male 3B	Male IV	Female All	Female 1-3A	Female 3B	Female IV
MM								
105	52.3	67.5	25.0	12.9	14.7	21.5	1.8	0.3
100	65.9	80.4	40.2	25.0	26.8	37.8	5.9	2.6
95	79.5	90.6	59.9	45.9	45.6	59.9	18.8	10.7
90	88.8	95.8	76.5	67.5	65.2	78.3	40.6	27.8
MM_3SSS								
105	48.8	61.7	25.8	14.7	8.6	12.6	1.1	0.6
100	61.4	74.3	38.5	25.0	16.5	23.6	3.1	1.5
95	73.1	84.6	52.8	40.2	28.6	39.2	8.3	3.9
90	83.1	91.8	67.7	56.8	44.2	57.2	19.6	12.9
MM-9								
105	50.8	67.9	19.9	7.3	13.3	20.1	0.5	0.3
100	64.3	81.4	33.8	16.2	24.4	36.2	2.0	0.6
95	76.6	91.2	51.1	30.2	39.6	56.6	7.3	1.9
90	86.8	96.8	69.7	50.4	58.3	77.9	21.3	7.2

Note: MM is the existing composite, based on 4 subtests, including NO subtest.
MM_3SSS is the existing unit-weighted composite, but excluding NO subtest.
MM-9 is the interim composite, based on 7 subtests after deletion of NO and CS from the battery.

Estimation of the New / Interim Composite Weights

This section summarizes how to obtain the AA composite weights (referred to as "u and k" values in the source research reports, and incorporated into the subtest weights shown in Tables 4 and 5) for operational use in the applicant Youth Population.[17] The validity coefficients we wish to maximize in the Youth Population actually exist only in doubly restricted MOS samples containing the Skill Qualifications Test (SQT) criterion in the 1987 - 1989 research data set. Appropriate corrections have to be made to these restricted validity coefficients to obtain unrestricted validity coefficients that, if subjected to restriction in range effects, would equal what was obtained in the MOS samples. We also have to estimate what the criterion standard deviation (SD) would have to be in the unrestricted population to yield the criterion SDs observed in the MOS samples.[18]

Our values of u and k used in conjunction with operational ASVAB subtest scores provide composite test scores with weights that maximize the correlation coefficients between composite test

[17] The methodology summarized here pertains to the development of both interim and new (17 job family) composites. For a detailed discussion of estimation in the face of restriction in range, see Appendix D.
[18] It should be noted that whenever validity coefficients are mentioned, we are assuming that these coefficients have been corrected for attenuation with respect to criterion unreliability. Even if we should refer to an uncorrected validity coefficient (for restriction in range), this "uncorrected" coefficient has been corrected for attenuation.

scores (when all weights are constrained to be positive or zero) and aggregated criterion scores that represent the MOS of each specified aptitude area. The correlation coefficient to be maximized is computed using restriction-in-range corrections that make the coefficient a best estimate of what it would have to be for the measured restriction effects to have the effect of reducing the Youth Population correlation coefficient to the magnitude observed in the restricted MOS sample. The validity coefficients and criterion scores aggregated across MOS samples to represent each aptitude area are doubly restricted since the soldiers in these MOS samples have been selected into the Army and classified and assigned to the MOS in which each validity is computed. Each such validity coefficient is corrected to provide an estimate of what the validity coefficient would be if the criterion were perfectly reliable.

The incorporation of restriction in range corrections into procedures for assuring that best weighted composites have an expected mean of 100 and standard deviation of 20 in the Youth Population can be summarized as follows:

1. Obtain the corrected subtest validity coefficients in each MOS sample. This correction is for the unreliability of the criterion and for the effect of double restriction in range on the predictors and criterion variables in each MOS sample. This step provides the subtest validity coefficients corrected to the Youth Population.

2. For each subtest multiply each corrected test validity by the density of that MOS and then sum these products across the set of MOSs contained in each job family to provide an estimate of each subtest validity (against a hypothetical job family criterion) within the restricted job family.

3. Use these job family subtest validity coefficients and the inter-correlation coefficients among the subtests to compute all positive or zero regression weights that are appropriate for applying to subtest standard scores (SSSs) to provide LSEs of the criterion. We find and compute those positive Beta weights (i.e., B-weights) that maximize the prediction of the criterion (as measured by multiple correlation coefficients) for all possible subsets of B-weights.

4. Separately for each job family, determine expected SDs of the hypothetical job family criterion variables as expected in the Youth Population. Setting the SDs of the subtest scores to 10, and using these criterion SDs, compute the raw score regression weights (i.e., b-weights) by converting each B-weight. Note that the resulting b-weighted composites will have SDs equal to values less than 10 because of the effects of the positive inter-correlation coefficients among the subtests.

5. Transform the b-weights into u,k values that provide composite scores with expected SDs equal to 20 and means equal to 100 when applied to operational subtest scores. (a) To do this we multiply each b-weight by a composite multiplier (CM) that will convert the composite to have a SD of 20 without considering the composite mean. (b) In the next step, the constant is calculated to center the composite at 100.

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APPENDIX A
9 AA Composites vs. 17 LSE Composites

1. 17 LSE composite validities
2. 17 LSE composite correlations
3. Nine bar charts comparing existing AA composites with new 17 LSE composites
    a. Existing composites shown in gray
    b. New composites shown in black and white
    c. Job families / aptitude areas are as follows: Clerical (CL); Combat (CO); Electronics Repair (EL); Field Artillery (FA); General Maintenance (GM); Mechanical Maintenance (MM); Operators / Food (OF); Surveillance / Communications (SC); Skilled Technical (ST)
    d. ASVAB subtests are as follows: general science (gs); arithmetic reasoning (ar); auto & shop information (as); mathematics knowledge (mk); mechanical comprehension (mc); electronics information (ei); verbal (ve); coding speed (cs); numerical operations (no)

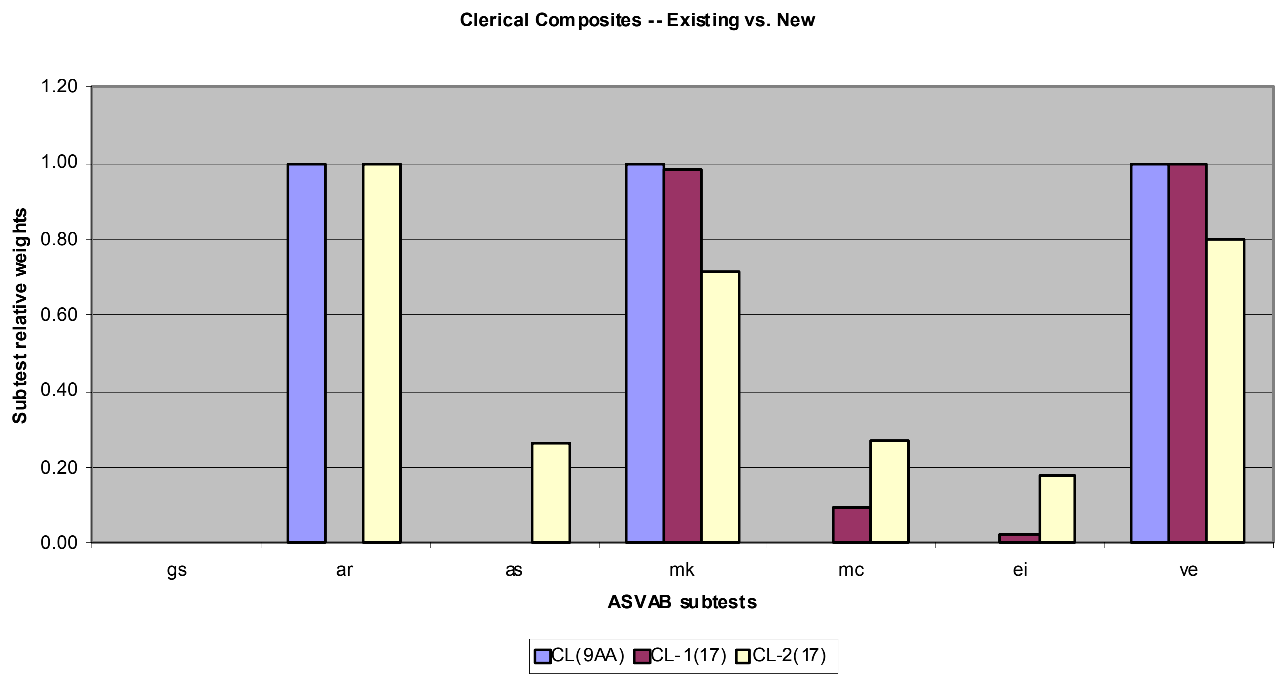
PROPOSED NEW COMPOSITES: 17 LSE

17 LSE COMPOSITE VALIDITIES

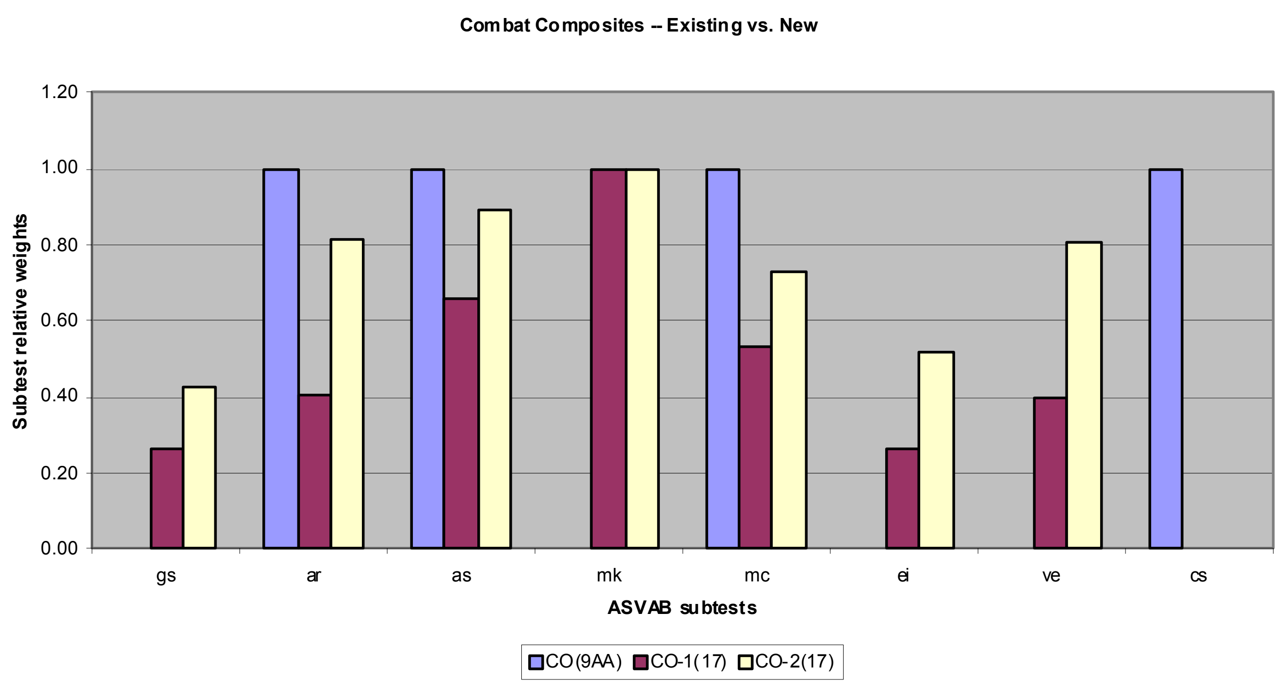
CL1	CL2	CO1	CO2	EL1	EL2	EL3	FA	GM1	GM2	MM1	MM2	OF	SC	ST1	ST2	ST3
0.713	0.654	0.525	0.64	0.675	0.682	0.718	0.594	0.767	0.639	0.762	0.748	0.657	0.661	0.607	0.719	0.72

17 LSE COMPOSITE CORRELATIONS

	CL1	CL2	CO1	CO2	EL1	EL2	EL3	FA	GM1	GM2	MM1	MM2	OF	SC	ST1	ST2	ST3
CL1	1.000	0.965	0.930	0.927	0.921	0.936	0.970	0.933	0.898	0.906	0.799	0.922	0.908	0.958	0.949	0.976	0.958
CL2	0.965	1.000	0.980	0.981	0.978	0.985	0.995	0.985	0.970	0.969	0.897	0.979	0.975	0.994	0.991	0.996	0.994
CO1	0.930	0.980	1.000	0.998	0.994	0.998	0.977	0.999	0.993	0.997	0.956	0.993	0.994	0.992	0.993	0.975	0.991
CO2	0.927	0.981	0.998	1.000	0.998	0.999	0.982	0.999	0.997	0.998	0.961	0.997	0.998	0.994	0.996	0.979	0.994
EL1	0.921	0.978	0.994	0.998	1.000	0.997	0.981	0.995	0.997	0.996	0.966	0.998	0.998	0.992	0.993	0.976	0.992
EL2	0.936	0.985	0.998	0.999	0.997	1.000	0.985	0.999	0.995	0.996	0.953	0.996	0.995	0.997	0.996	0.982	0.995
EL3	0.970	0.995	0.977	0.982	0.981	0.985	1.000	0.982	0.970	0.968	0.901	0.982	0.976	0.994	0.994	0.999	0.996
FA	0.933	0.985	0.999	0.999	0.995	0.999	0.982	1.000	0.993	0.996	0.952	0.995	0.996	0.995	0.996	0.981	0.994
GM1	0.898	0.970	0.993	0.997	0.997	0.995	0.970	0.993	1.000	0.998	0.974	0.995	0.998	0.986	0.988	0.964	0.985
GM2	0.906	0.969	0.997	0.998	0.996	0.996	0.968	0.996	0.998	1.000	0.974	0.995	0.997	0.986	0.988	0.964	0.985
MM1	0.799	0.897	0.956	0.961	0.966	0.953	0.901	0.952	0.974	0.974	1.000	0.965	0.972	0.929	0.935	0.889	0.930
MM2	0.922	0.979	0.993	0.997	0.998	0.996	0.982	0.995	0.995	0.995	0.965	1.000	0.999	0.991	0.994	0.977	0.993
OF	0.908	0.975	0.994	0.998	0.998	0.995	0.976	0.996	0.998	0.997	0.972	0.999	1.000	0.988	0.992	0.971	0.989
SC	0.958	0.994	0.992	0.994	0.992	0.997	0.994	0.995	0.986	0.986	0.929	0.991	0.988	1.000	0.997	0.992	0.998
ST1	0.949	0.991	0.993	0.996	0.993	0.996	0.994	0.996	0.988	0.988	0.935	0.994	0.992	0.997	1.000	0.992	0.999
ST2	0.976	0.996	0.975	0.979	0.976	0.982	0.999	0.981	0.964	0.964	0.889	0.977	0.971	0.992	0.992	1.000	0.995
ST3	0.958	0.994	0.991	0.994	0.992	0.995	0.996	0.994	0.985	0.985	0.930	0.993	0.989	0.998	0.999	0.995	1.000



Clerical Composites -- Existing vs. New
Subtest relative weights
1.20
1.00
0.80
0.60
0.40
0.20
0.00
gs
ar
as
mk
mc
ei
ve
ASVAB subtests
CL(9AA)
CL-1(17)
CL-2(17)



Combat Composites -- Existing vs. New
Subtest relative weights
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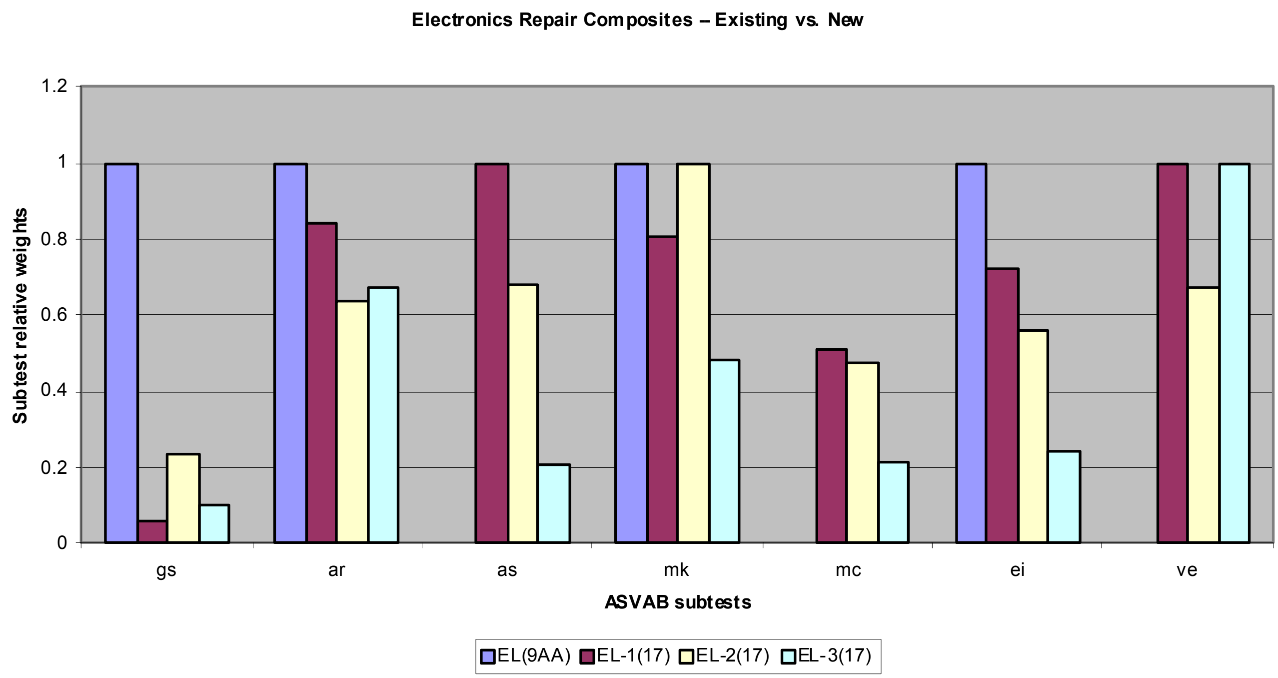
1.00
0.80
0.60
0.40
0.20
0.00
gs
ar
as
mk
mc
ei
ve
cs
ASVAB subtests
CO(9AA)
CO-1(17)
CO-2(17)


Electronics Repair Composites – Existing vs. New
Subtest relative weights
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0.6
0.4
0.2
0
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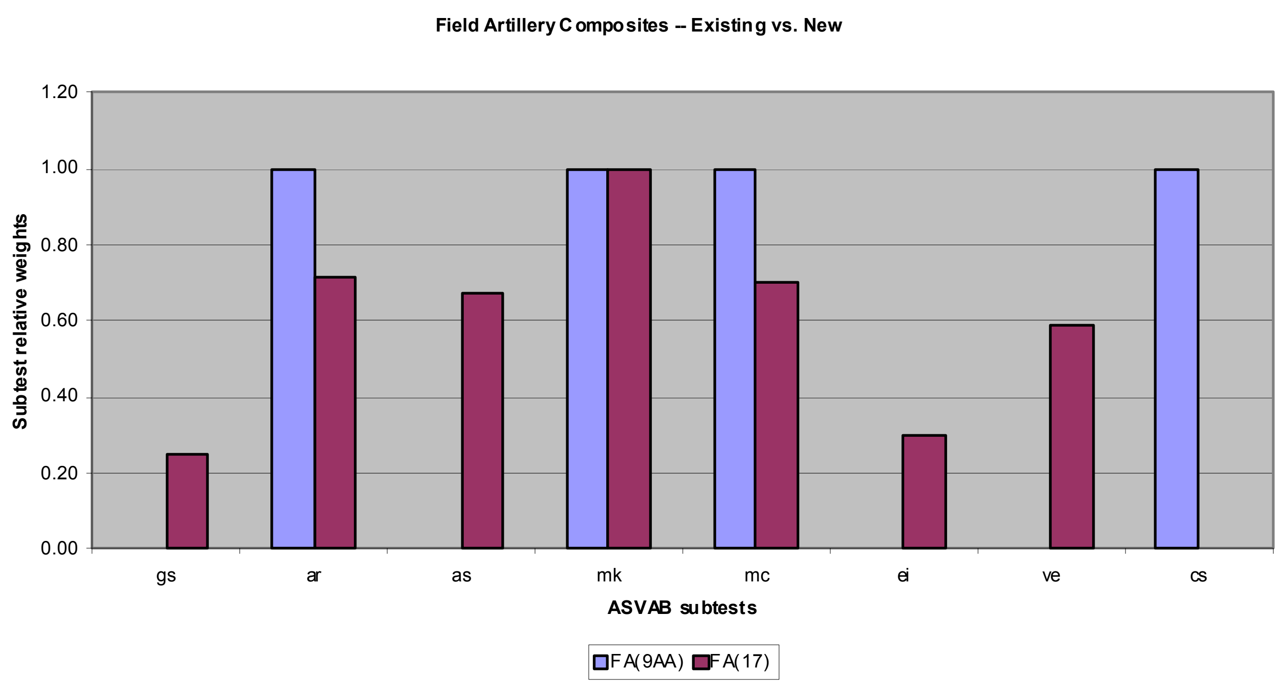
as
mk
mc
ei
ve
ASVAB subtests
EL(9AA)
EL-1(17)
EL-2(17)
EL-3(17)


Field Artillery Composites – Existing vs. New
Subtest relative weights
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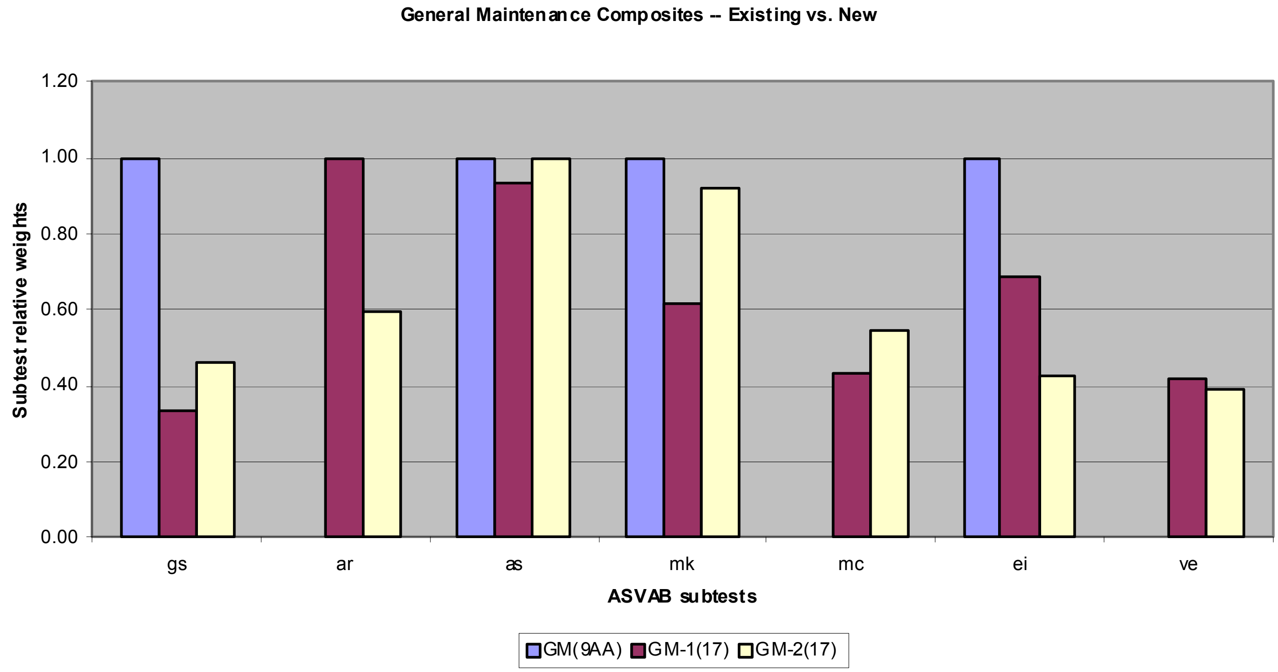
1.00
0.80
0.60
0.40
0.20
0.00
gs
ar
as
mk
mc
ei
ve
cs
ASVAB subtests
FA(9AA)
FA(17)


General Maintenance Composites -- Existing vs. New
Subtest relative weights
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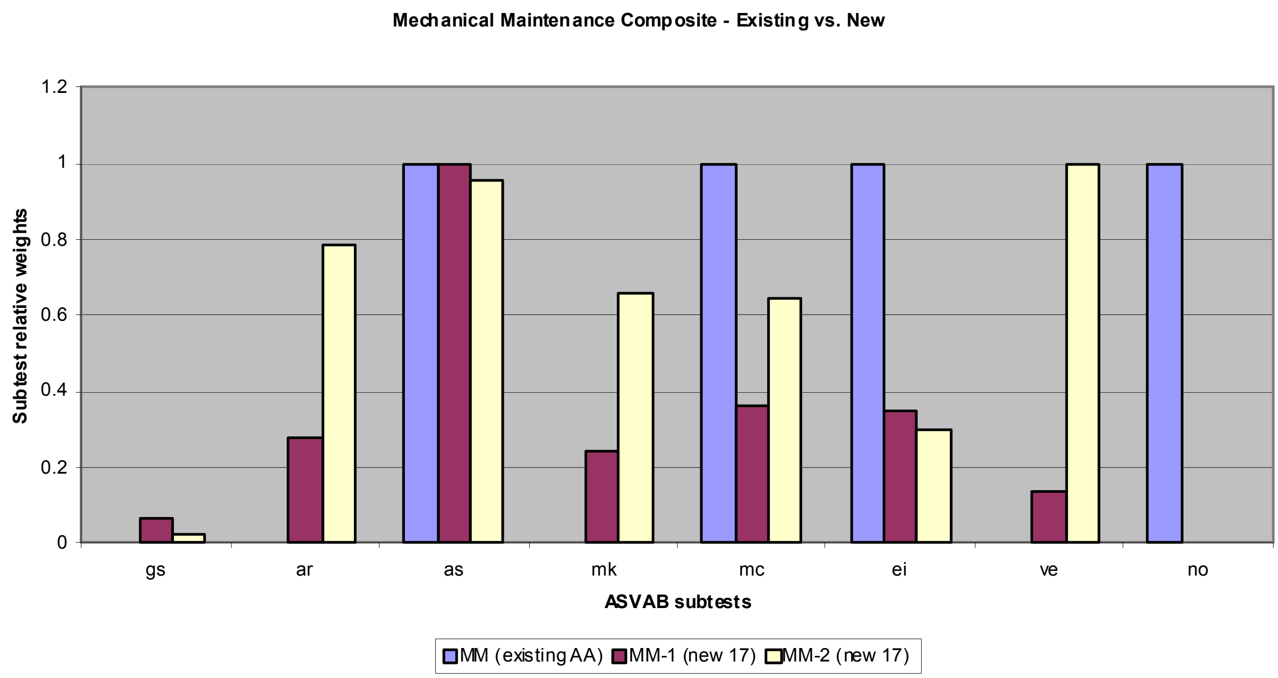
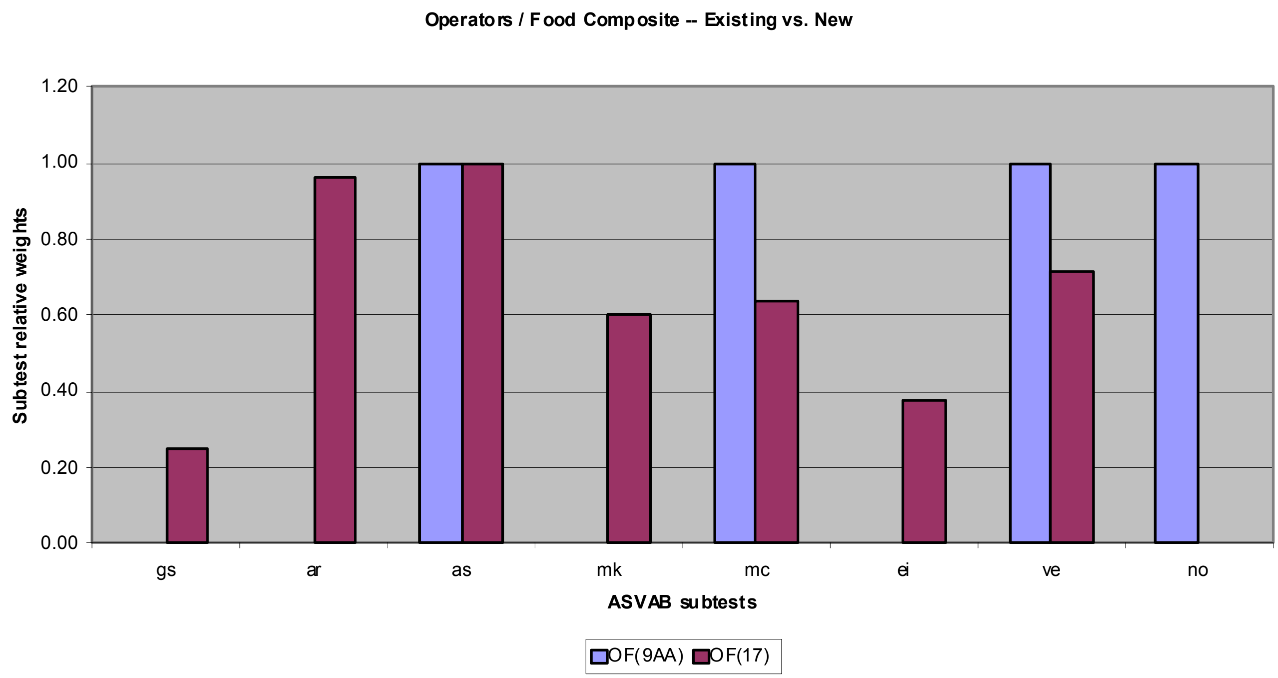
1.00
0.80
0.60
0.40
0.20
0.00
gs
ar
as
mk
mc
ei
ve
ASVAB subtests
GM(9AA)
GM-1(17)
GM-2(17)


Mechanical Maintenance Composite - Existing vs. New
Subtest relative weights
1.2
1
0.8
0.6
0.4
0.2
0
gs
ar
as
mk
mc
ei
ve
no
ASVAB subtests
MM (existing AA)
MM-1 (new 17)
MM-2 (new 17)


Operators / Food Composite -- Existing vs. New
Subtest relative weights
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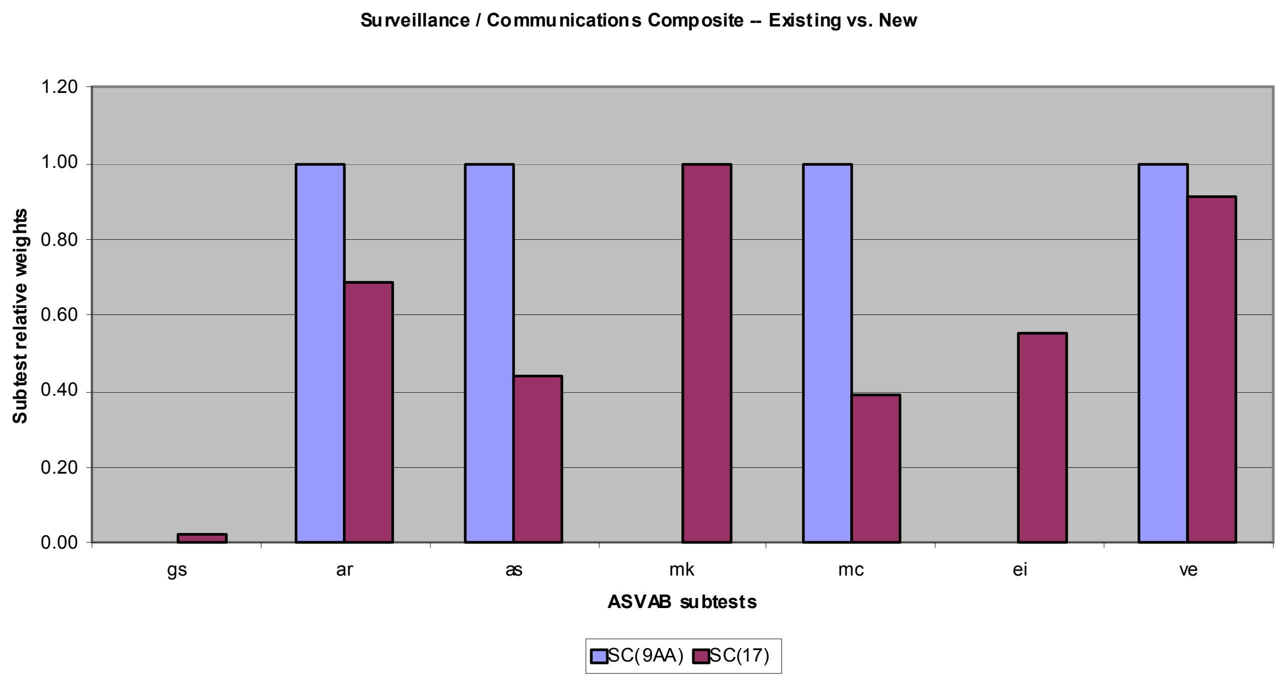
1.00
0.80
0.60
0.40
0.20
0.00
gs
ar
as
mk
mc
ei
ve
no
ASVAB subtests
OF(9AA)
OF(17)


Surveillance / Communications Composite -- Existing vs. New
Subtest relative weights
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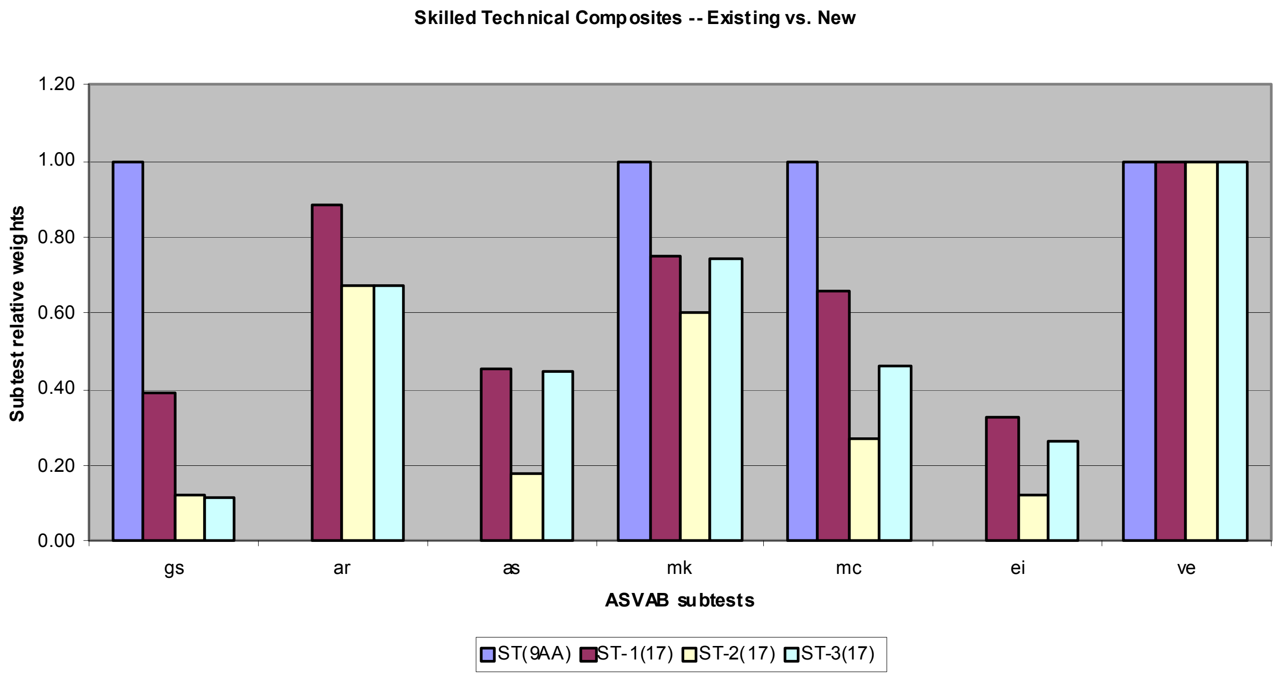
0.80
0.60
0.40
0.20
0.00
gs
ar
as
mk
mc
ei
ve
ASVAB subtests
SC(9AA)
SC(17)


Skilled Technical Composites -- Existing vs. New
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Subtest relative weights
gs
ar
as
mk
mc
ei
ve
ASVAB subtests
ST(9AA)
ST-1(17)
ST-2(17)
ST-3(17)

APPENDIX B

MOS Membership in 17 Job Family Structure

17 Job Family Structure:

1 = Clerical-1; 2 = Clerical-2
3 = Combat-1; 4 = Combat-2
5 = Electronics Repair-1; 6 = Electronics Repair-2; 7 = Electronics Repair-3
8 = Field Artillery
9 = General Maintenance-1; 10 = General Maintenance-2
11 = Mechanical Maintenance-1; 12 = Mechanical Maintenance-2
13 = Operators / Food
14 = Surveillance / Communications
15 = Skilled Technical-1; 16 = Skilled Technical-2; 17 = Skilled Technical-3

12/20/01

Entry-level MOS List [PERSCOM 11/2/2001]

MOS	TITLE	CMF	** 17 Family
56M	Chaplain assistant	56	1
71D	Legal specialist - del 0110	71	1
71L	Administrative specialist	71	1
73C	Finance specialist	71	1
73D	Accounting specialist	71	1
75B	Personnel administration specialist	71	1
75F	Personnel information system management specialist	71	1
75H	Personnel services specialist	71	1
88N	Transportation management coordinator	88	1
77F	Petroleum supply specialist	77	2
92A	Automated logistical specialist	92	2
92Y	Unit supply specialist	92	2
11B	Infantryman	11	3
11C	Indirect fire infantryman	11	3
11H	Heavy antiarmor weapons infantryman	11	3
11M	Fighting vehicle infantryman	11	3
11X		11	3
12B	Combat engineer	12	4
12C	Bridge crewmember	12	4
19D	Cavalry scout	19	4
19K	M1 armor crewman	19	4
14E	Patriot fire control enhanced operator/maintainer	14	5
14L	AN/TSQ-73 air defense artillery command and control system operator/maintainer RC	14	5
14M	Man portable air defense system crewmember RC	14	5
14T	Patriot launching station enhanced operator/maintainer	14	5
23R	Hawk missile system mechanic - del 0110 RC	14	5
31L	Cable systems installer/maintainer	31	5
51R	Interior electrician	51	5
52G	Transmission and distribution specialist RC	51	5

68X	AH-64A armament/electrical systems repairer	67	5
13D	Field artillery tactical data systems specialist	13	6
25R	Visual information equipment operator/maintainer	25	6
25V	Combat documentation/production specialist	25	6
31F	Network switching systems operator/maintainer	31	6
31P	Microwave systems operator/maintainer	31	6
31S	Satellite communication systems operator/maintainer	31	6
31U	Signal support systems specialist	31	6
35Y	Integrated family of test equipment operator/maintainer	35	6
93F	Field artillery meteorological crewmember	13	6
96H	Imagery ground station operator	96	6
96R	Ground surveillance systems operator	96	6
27E	Land combat electronic missile system repairer	35	7
27G	Chaparral and Redeye repairer	35	7
27M	MLRS repairer	35	7
27T	Avenger system repairer	35	7
35B	LCSS test specialist	35	7
35D	Air traffic control equipment repairer	35	7
35E	Radio and communications security repairer	35	7
35F	Special electronic devices repairer	35	7
35H	Test, measurement, and diagnostic equipment maintenance support specialist	35	7
35J	Computer/automation system repairer	35	7
35L	Avionic communication equipment repairer	35	7
35M	Radar repairer	35	7
35N	Wire systems equipment repairer	35	7
35R	Avionics systems repairer	35	7
39B	Automatic test equipment operator/maintainer	35	7
45G	Fire control repairer	63	7
68J	Aircraft armament/missile systems repairer	67	7
68N	Avionic / mechanic	67	7
68S	OH-58D armament/electrical/avionics systems repairer	67	7
68Y	AH-64D armament/electrical/avionic systems repairer	67	7
13B	Cannon crewmember	13	8
13C	Tactical automated fire control systems specialist	13	8
13E	Cannon fire direction specialist	13	8
13F	Fire support specialist	13	8
13P	MLRS operations/fire direction specialist	13	8
44B	Metal worker	63	9
44E	Machinist	63	9
45B	Small arms/artillery repairer	63	9
45D	Self-propelled field artillery turret mechanic	63	9
45K	Armament repairer	63	9
45T	Bradley fighting vehicle system turret mechanic	63	9
52C	Utilities equipment repairer	63	9
52D	Power-generation equipment repairer	63	9
43M	Fabric repair specialist - del 0110	92	10
51B	Carpentry and masonry specialist	51	10
51K	Plumber	51	10
51M	Firefighter	51	10

55B	Ammunition specialist	55	10
55D	Explosive ordnance disposal specialist	55	10
62E	Heavy construction equipment operator	51	10
62F	Crane operator	51	10
62G	Quarrying specialist RC	51	10
62H	Concrete and asphalt equipment operator	51	10
62J	General construction equipment operator	51	10
77W	Water treatment specialist	77	10
88H	Cargo specialist	88	10
92M	Mortuary affairs specialist	92	10
92R	Parachute rigger	92	10
92S	Laundry and textile specialist	92	10
45E	M1 Abrams tank turret mechanic	63	11
45N	M60A1/A3 tank turret mechanic RC	63	11
62B	Construction equipment repairer	63	11
63A	M1 Abrams tank system maintainer	63	11
63B	Light-wheel vehicle mechanic	63	11
63D	Self-propelled field artillery system mechanic	63	11
63E	M1 Abrams tank system mechanic	63	11
63G	Fuel and electrical systems repairer	63	11
63H	Track vehicle repairer	63	11
63J	Quartermaster and chemical equipment repairer	63	11
63M	Bradley fighting vehicle system maintainer	63	11
63N	M60A1/A3 tank system mechanic RC	63	11
63S	Heavy-wheel vehicle mechanic	63	11
63T	Bradley fighting vehicle system mechanic	63	11
63W	Wheel vehicle repairer	63	11
63Y	Track vehicle mechanic	63	11
88K	Watercraft operator	88	11
88L	Watercraft engineer	88	11
88P	Railway equipment repairer RC	88	11
88T	Railway section repairer RC	88	11
88U	Railway operations crewmember RC	88	11
67G	Utility airplane repairer RC	67	12
67N	UH-1 helicopter repairer	67	12
67R	AH-64 attach helicopter repairer	67	12
67S	OH-58D helicopter repairer	67	12
67T	UH-60 helicopter repairer	67	12
67U	CH-47 helicopter repairer	67	12
67V	Observation/scout helicopter repairer	67	12
67Y	AH-1 attack helicopter repairer	67	12
68B	Aircraft powerplant repairer	67	12
68D	Aircraft powertrain repairer	67	12
68F	Aircraft electrician	67	12
68G	Aircraft structural repairer	67	12
68H	Aircraft pneudraulics repairer	67	12
13M	Multiple launch rocket system crewmember	13	13
14D	Hawk missile system crewmember RC	14	13
14J	Air defense command, control, communications, computers, and intelligence tactical operations center enhanced	14	13

	operator/maintainer		
14R	Bradley linebacker crewmember	14	13
14S	Avenger crewmember	14	13
88M	Motor transport operator	88	13
91M	Hospital food service specialist	91	13
92G	Food service specialist	92	13
13R	Field artillery firefinder radar operator	13	14
31C	Radio operator-maintainer	31	14
31R	Multi-channel transmission systems operator/maintainer	31	14
74C	Telecommunications operator/maintainer	74	14
77L	Petroleum laboratory specialist	77	15
91A	Medical equipment repairer	91	15
91D	Operating room specialist	91	15
91E	Dental specialist	91	15
91G	Patient administration specialist	91	15
91H	Optical laboratory specialist	91	15
91J	Medical logistics specialist	91	15
91K	Medical laboratory specialist	91	15
91P	Radiology specialist	91	15
91Q	Pharmacy specialist	91	15
91R	Veterinary food inspection specialist	91	15
91S	Preventive medicine specialist	91	15
91T	Animal care specialist	91	15
91X		91	15
25M	Multimedia illustrator	25	16
33W	Intelligence and electronic warfare system repairer	33	16
37F	Psychological operations specialist	37	16
38A	Civil affairs specialist RC	38	16
46Q	Journalist	46	16
46R	Broadcast journalist	46	16
51T	Technical engineer	51	16
74B	Information systems operator/analyst	74	16
81L	Lithographer	81	16
81T	Topographic analyst	81	16
82D	Topographic surveyor	81	16
96B	Intelligence analyst	96	16
96D	Imagery analyst	96	16
96U	Unmanned aerial vehicle operator	96	16
97B	Counter-intelligence agent	96	16
97L	Translator/interpreter	96	16
98C	Signals intelligence analyst	98	16
98H	Communications locator/interceptor	98	16
98J	Electronic intelligence interceptor/analyst	98	16
98K	Signal collection/identification analyst	98	16
98X		98	16
54B	Chemical operations specialist	54	17
82C	Field artillery surveyor	13	17
93C	Air traffic control operator	93	17
93P	Aviation operations specialist	93	17
95B	Military police	95	17

95C	Internment/resettlement specialist	95	17
00B	Diver	51	
13W	Field artillery meteorological crewmember - add 0304	13	
13X	Field artillery computer systems specialist	13	
27D	Paralegal specialist	27	
91Z	Chief medical NCO	91	

APPENDIX C
9 AA Composites vs. 9 LSE (Interim) Composites

1. 9 LSE composite validities
2. 9 LSE composite correlations
3. Nine bar charts comparing existing 9 AA composites with interim 9 LSE composites
    a. Existing composites shown in gray
    b. Interim composites shown in black
    c. Job families / aptitude areas are as follows: Clerical (CL); Combat (CO); Electronics Repair (EL); Field Artillery (FA); General Maintenance (GM); Mechanical Maintenance (MM); Operators / Food (OF); Surveillance / Communications (SC); Skilled Technical (ST)
    d. ASVAB subtests are as follows: general science (gs); arithmetic reasoning (ar); auto & shop information (as); mathematics knowledge (mk); mechanical comprehension (mc); electronics information (ei); verbal (ve); coding speed (cs); numerical operations (no)

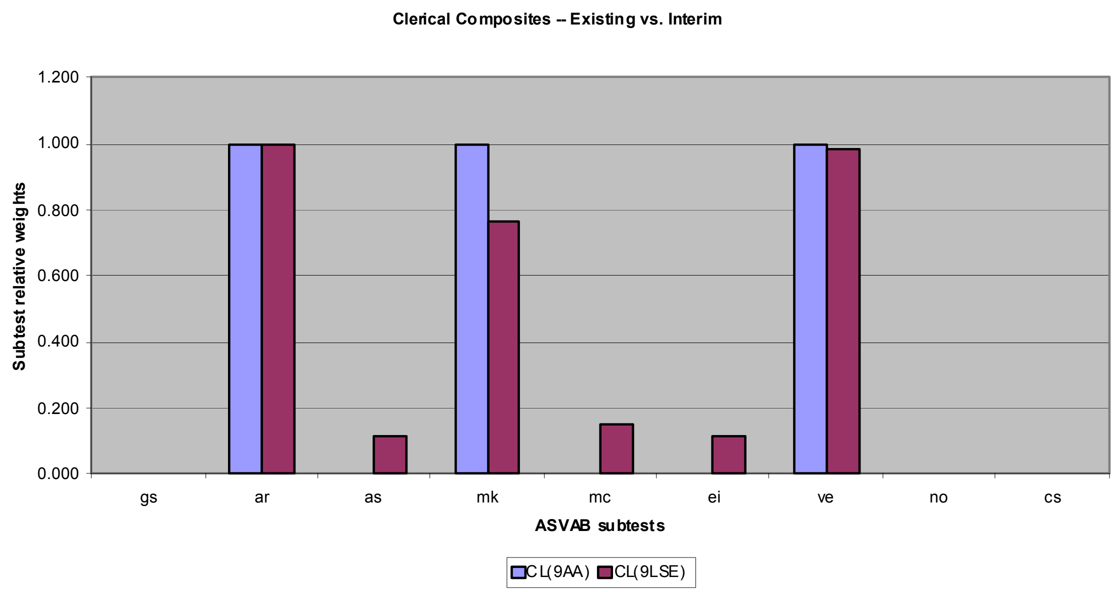
INTERIM COMPOSITES
9-LSE COMPOSITE VALIDITIES AND CORRELATIONS

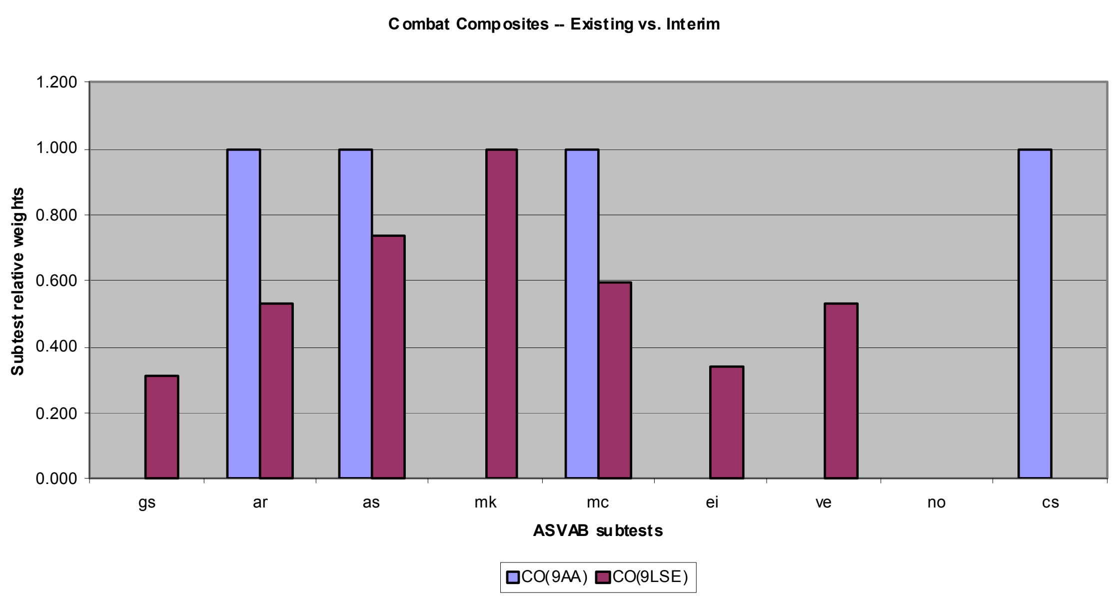
9 LSE COMPOSITE VALIDITIES

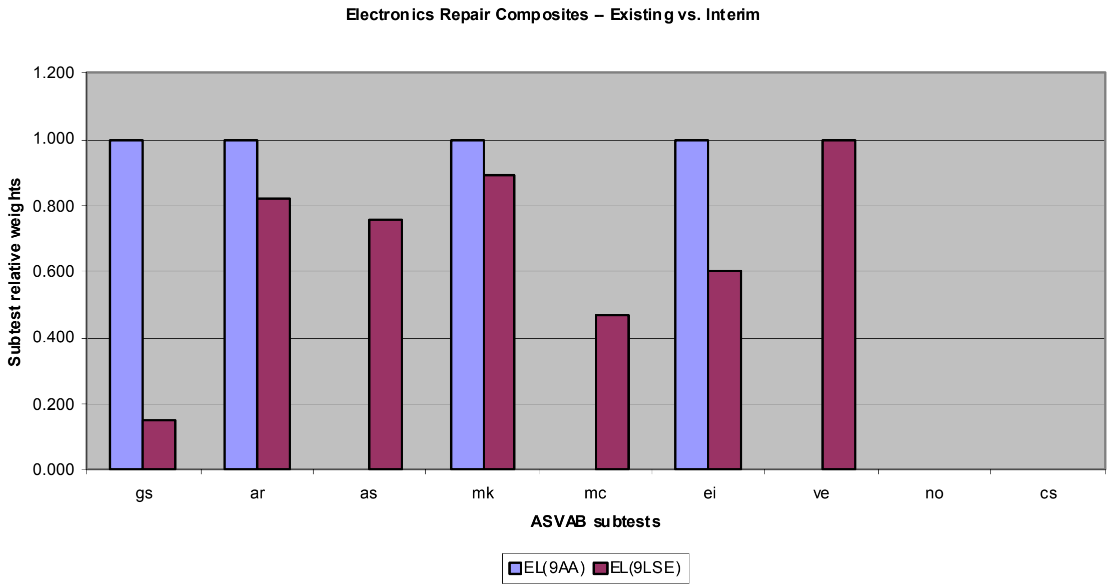
CL	CO	EL	FA	GM	MM	OF	SC	ST
0.677	0.566	0.684	0.594	0.698	0.756	0.657	0.661	0.679

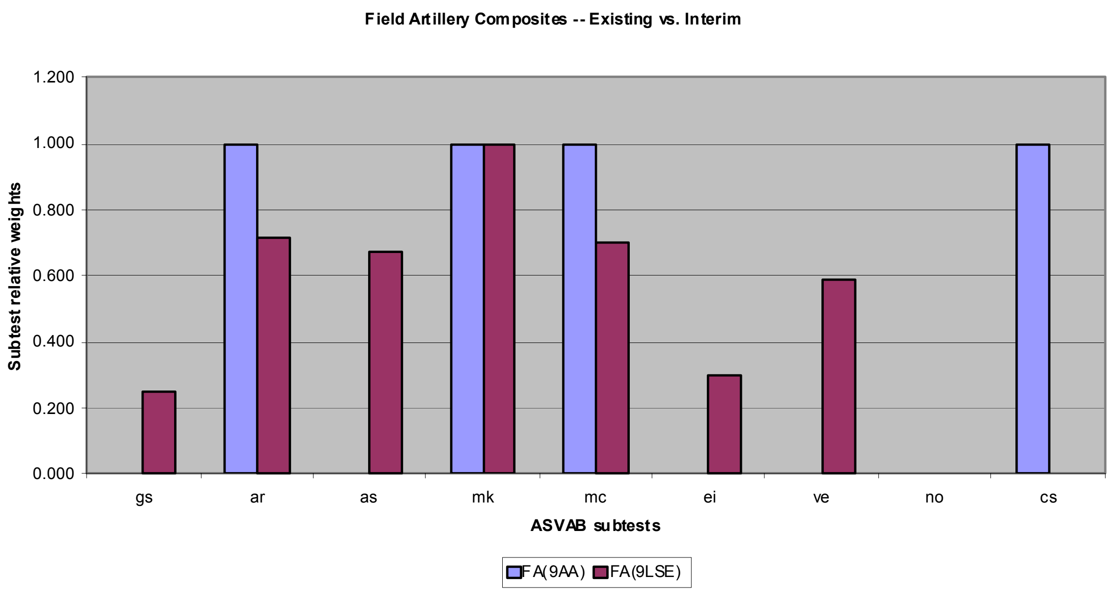
9 LSE COMPOSITE VALIDITIES

	CL	CO	EL	FA	GM	MM	OF	SC	ST
CL	1.000	0.963	0.973	0.969	0.948	0.883	0.954	0.984	0.988
CO	0.963	1.000	0.997	0.999	0.997	0.971	0.996	0.993	0.990
EL	0.973	0.997	1.000	0.997	0.994	0.965	0.996	0.997	0.996
FA	0.969	0.999	0.997	1.000	0.995	0.965	0.996	0.995	0.993
GM	0.948	0.997	0.994	0.995	1.000	0.983	0.998	0.986	0.982
MM	0.883	0.971	0.965	0.965	0.983	1.000	0.982	0.946	0.939
OF	0.954	0.996	0.996	0.996	0.998	0.982	1.000	0.988	0.986
SC	0.984	0.993	0.997	0.995	0.986	0.946	0.988	1.000	0.998
ST	0.988	0.990	0.996	0.993	0.982	0.939	0.986	0.998	1.000

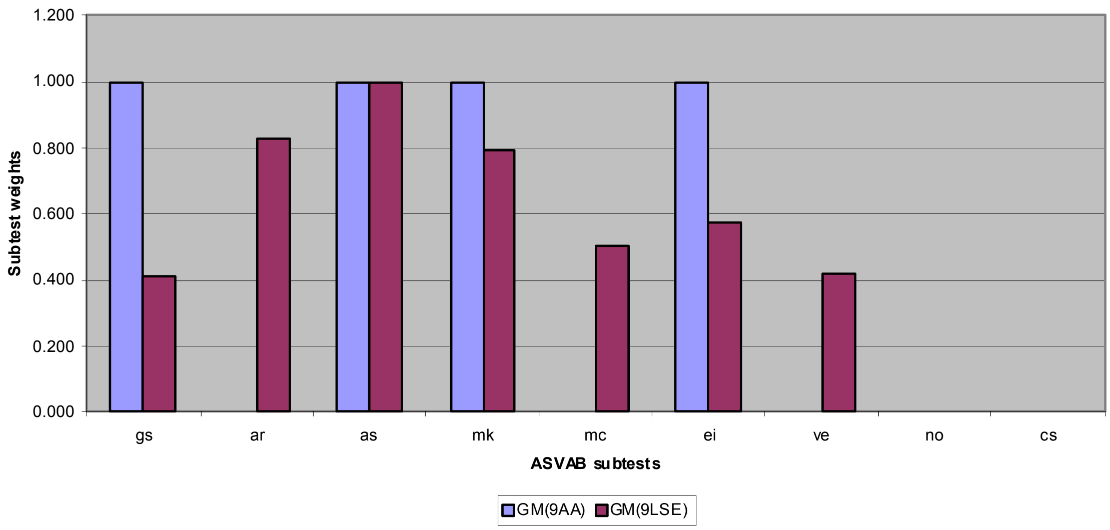

Clerical Composites -- Existing vs. Interim
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Subtest relative weights
gs
ar
as
mk
mc
ei
ve
no
cs
ASVAB subtests
CL(9AA)
CL(9LSE)


Combat Composites -- Existing vs. Interim
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Subtest relative weights
gs
ar
as
mk
mc
ei
ve
no
cs
ASVAB subtests
CO(9AA)
CO(9LSE)

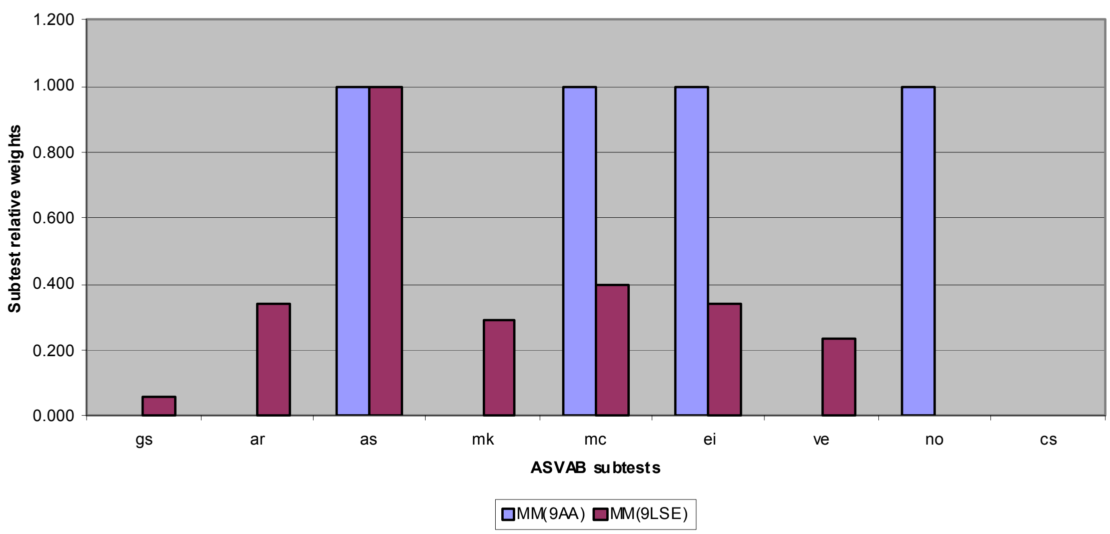

Electronics Repair Composites – Existing vs. Interim
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Subtest relative weights
gs
ar
as
mk
mc
ei
ve
no
cs
ASVAB subtests
EL(9AA)
EL(9LSE)


Field Artillery Composites -- Existing vs. Interim
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Subtest relative weights
gs
ar
as
mk
mc
ei
ve
no
cs
ASVAB subtests
FA(9AA)
FA(9LSE)

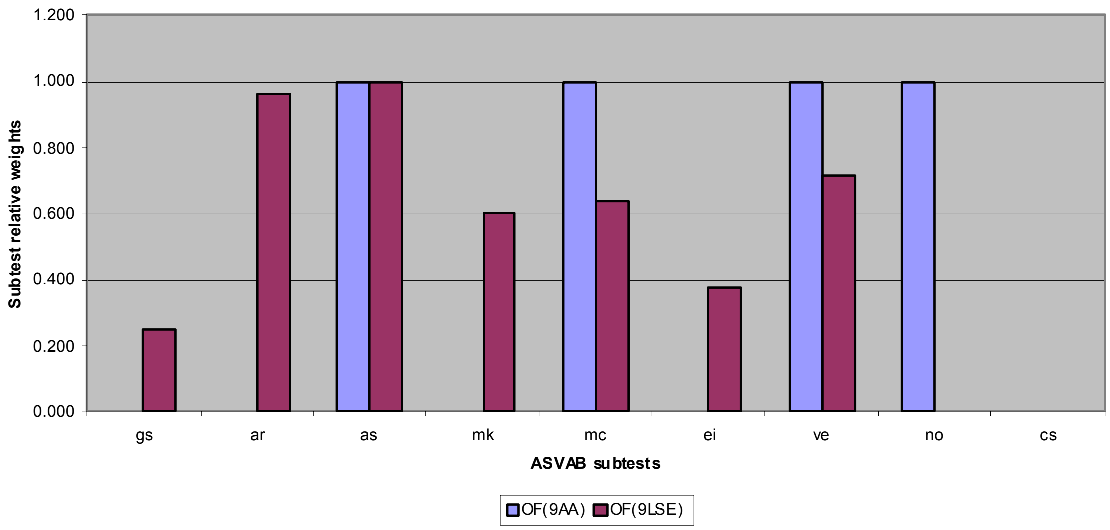
General Maintenance Composites – Existing vs.Interim



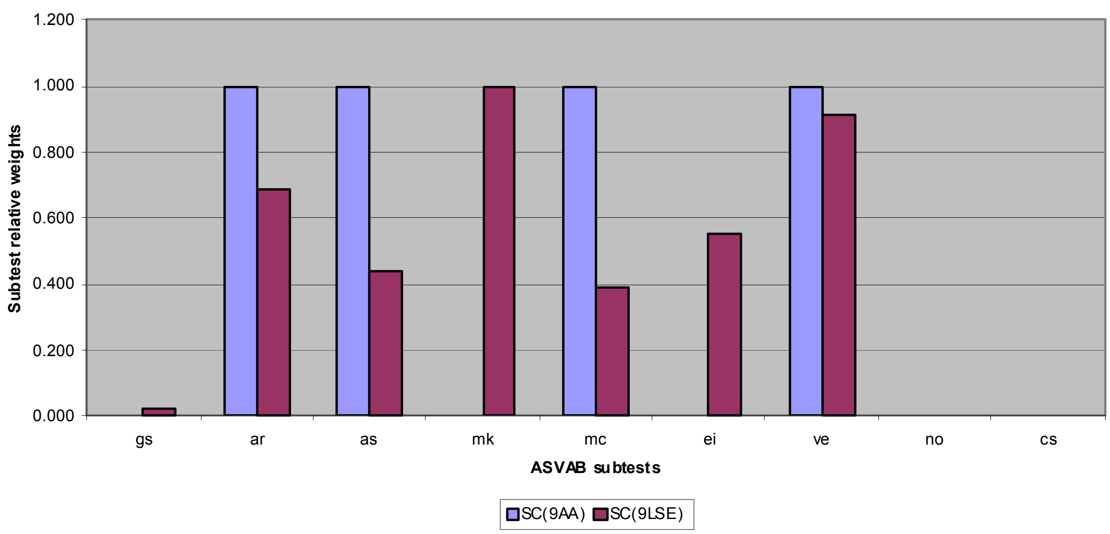
Mechanical Maintenance Composites – Existing vs. Interim

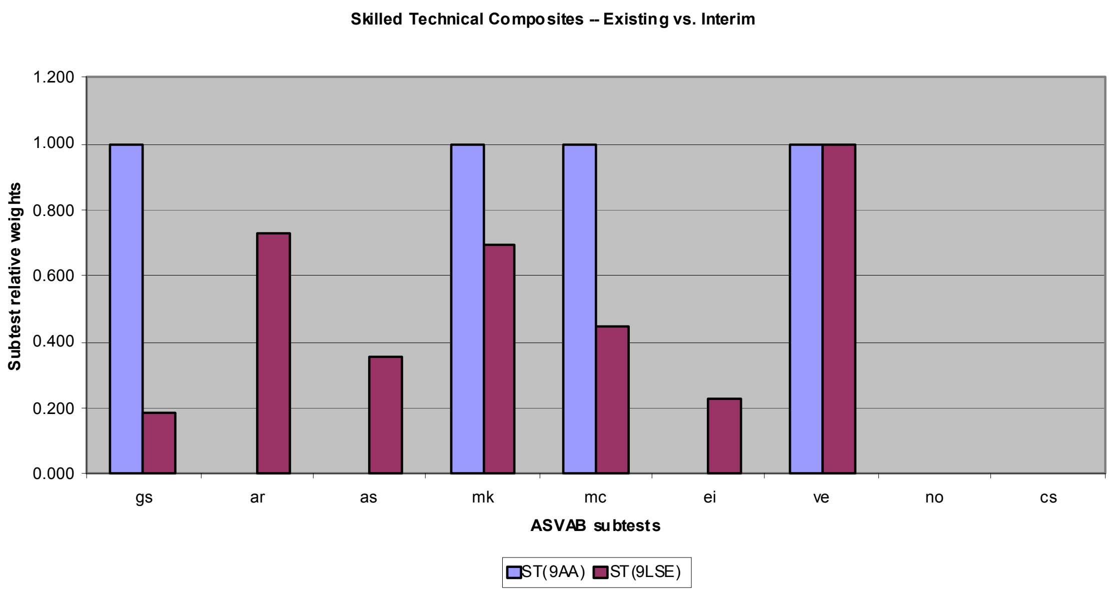


Operators / Food Composites -- Existing vs. Interim



Surveillance / Communications Composite – Existing vs. Interim




Skilled Technical Composites -- Existing vs. Interim
Subtest relative weights
1.200
1.000
0.800
0.600
0.400
0.200
0.000
gs
ar
as
mk
mc
ei
ve
no
cs
ASVAB subtests
ST(9AA)
ST(9LSE)

Appendix D
Restriction in Range and the Estimation of AA Composites

Introduction

This appendix will focus on how to obtain the AA composite regression weights (referred to as "u and k" values) for operational use in the applicant Youth Population.[19] The validity coefficients we wish to maximize in the Youth Population actually exist only in doubly restricted MOS samples containing the Skill Qualifications Test (SQT) criterion in the 1987 - 1989 research data set. Appropriate corrections have to be made to these restricted validity coefficients to obtain unrestricted validity coefficients that, if subjected to restriction in range effects, would equal what was obtained in the MOS samples. We also have to estimate what the criterion standard deviation (SD) would have to be in the unrestricted population to yield the criterion SDs observed in the MOS samples.[20]

The Army operational process involves an applicant Youth Population from which self-selection first occurs, and then the Recruiting Command selects some and rejects others using tests, medical examinations, security investigations etc. This results in an Army Input Population from which classification and assignment procedures and further self selection create the 150 MOS samples, each with its separate SQT criterion measure. Thus there is a selection stage and a classification and assignment stage, with a restriction in range effect on both test scores and hypothetical criterion scores occurring at both stages. If we confined selection effects to the impact of the AFQT screen, the selection and classification stage effects would have to be corrected in a sequential manner. However, since we are not restricting ourselves to such a limited selection effect, and are instead considering all effects on the subtest co-variances at each restriction stage, we can correct validity coefficients and criterion SDs directly to the Youth Population.

Our correction process for restriction in range involves contrasting, separately for each MOS, the within-MOS subtest variance/co-variances against the Youth Population operational test variance/co-variances. The differences in the variance/co-variances across the unrestricted and the restricted samples for variables specified as explicitly selected variables are the measures of the magnitude of the restriction effect. For our purposes we use all ASVAB subtests as the explicitly restricted variables and we designate the criterion variables as the implicitly restricted variables that are restricted to the extent that they are predicted by the explicitly restricted variables.

Using this concept we can calculate the effect selection has on subtest scores and can then calculate the further effect classification and assignment has on test scores in the

[19] This appendix has been prepared by Cecil Johnson, consulting research psychologist.
[20] It should be noted that whenever validity coefficients are mentioned, we are assuming that these coefficients have been corrected for attenuation with respect to criterion unreliability. Even if we should refer to an uncorrected validity coefficient (for restriction in range), this "uncorrected" coefficient has been corrected for attenuation.

Army Input Population – to arrive at the doubly restricted subtest scores in the MOS samples. Considering the correlation of the subtest scores with the criterion scores and the amount of restriction occurring at each stage, we can determine the restriction effect on the hypothetical criterion scores and then provide a correction extending from the MOS criterion scores to the less restricted populations where the criterion scores exist only as a function of the subtest scores (i.e., as predicted criterion scores).

Approach

There is more than one algebraically equivalent way of providing operational u and k values when criterion scores are only available on the doubly restricted MOS samples. We will use an approach that utilizes the equality of G-weights computed in the restricted and the unrestricted population (using Gulliksen's formulation as described below). The G-weights computed in the restricted population samples will be used as a substitute for the unobtainable G-weights in the unrestricted population in Gulliksen's formula for computing the criterion variance in the unrestricted population.

1. Consider the matrix of G-weights, G, in each MOS sample. Our use for G is as an entry value in Gulliksen's formula (see below). The corrected validity coefficients, obtained with the use of the formula at either or both the Army Input Population and Youth Population points, were then employed in computing Beta weights in the Youth Population. Note that this correction must be made from each MOS sample to the Youth population to produce validity coefficients corrected for restriction in range. These corrected MOS validity coefficients are then aggregated into a corrected validity for each specified family, using acquisition values to weight the MOS validity coefficients corrected to the Youth Population.
2. Visualize a composite computed for an individual by summing the product of each subtest standard score (X) and B. The best weighted composite XB will have a SD equal to the validity of predicted performance (PP) in the Youth Population if the elements of the V matrix used in computing B are validity coefficients corrected for restriction in range to represent the Youth Population, and the R matrix consists of the inter-correlation coefficients among subtests as expected in the Youth Population. The criterion variables, predicted as least square estimates (LSEs) by the PP composites, have a SD equal to 1.0 in the restricted MOS samples, while the hypothetical unrestricted criterion variables would have larger SDs in the less restricted populations. Compute the Youth Population beta weights as follows:

   $$B = R^{-1} V^{T},$$

   where R is the Youth Population matrix of subtest inter-correlation coefficients, V is the matrix of validity coefficients corrected to the Youth Population, and superscript T indicates transposition of the matrix. Looking at the formula in more detail,

   $$R = S_x C_{xx} S_x, \text{ and } V^{T} = S_x C_{xc} S_{c},$$

   where C represents criterion / subtest variance and co-variances found in Gulliksen's formulae, and S represents a diagonal matrix where each diagonal element is equal to a reciprocal of a SD.

3. Compute b-weights by converting the Beta weights computed in step 2. The b-weights that are appropriate to apply to operational test scores to obtain a least squares estimate (LSE) of the criterion can be defined in terms of the Beta weights, the SDs of the subtests, and the SDs of the criterion scores. These b-weights applied to the operational test scores would provide a composite that, if the appropriate regression constant were subtracted, would have a mean of 50 and a SD less than 10 (because of the effects of the positive inter-correlation coefficients among the subtests). The b-weights are computed, ignoring the regression constants, as follows:

$$\text{b-weight} = \text{B-weight} * (SD)_c \ / \ (SD)_t \,,$$

where t represents a subtest, $SD_t = 10$, and c represents the criterion variable.

4. The composite computed in step 3 will have a SD less than 10. We wish to convert this composite to have a SD of 20. To do this we will multiply each b-weight by a composite multiplier (CM) that will convert the composite to have a SD of 20 without affecting the composite mean. CM can be computed as follows.

$$CM = 20 \ / \ (10 * (\underline{b}R\underline{b}^T)^{1/2}),$$

where $\underline{b}$ is a vector of b-weights and R is the Youth Population matrix of subtest inter-correlation coefficients.

5. We can now compute the u and k values (i.e., the operational subtest weights) for each composite:

$$u_j \ = \ CM * \text{b-weight of the j-th subtest}$$

$$k = \ 100 - \ \sum u_j * 50$$

Key Formulae From Gulliksen

The algorithms we use to correct for restriction in range due to “selection” effects are developed and described by Gulliksen (1950)[21]. His development is based on a model that visualizes the presence of both explicit and implicit selection processes in the unrestricted population, and the presence of both explicitly and implicitly selected variables in the restricted population. Thus, both explicit and implicit variables are present in both the unrestricted and restricted populations. The author shows, in the context of this model, relationships among the restricted and unrestricted variances/co-variances without relaxing flexibility as to which population contains the unknowns that cannot be directly computed but can be determined on the basis of the relationships defined in his model.

The Gulliksen formulae for correcting variances and/or co-variances for restriction in range effects are based on Lawley’s (1943) assumptions that include the following: (1) that the regression of the implicitly restricted variables on the explicitly restricted predictors is linear; (2) that the co-variance of the restricted variables exhibit homoscedasticity; and (3) that the G-weights for application to the population variance-

[21] See H. Gulliksen, *Theory of Mental Tests*. New York: John Wiley & Sons, 1950.

covariance matrix of operational test scores (explicitly restricted variables, e.g., sub-tests) are invariant to the effects of restriction (as defined). Thus it is assumed that

$$G = (C_{xx})^{-1} \; (C_{xc})^{T}$$

can be computed in a restricted population sample and substituted in formulae for use in the unrestricted population where a G-weight is to be entered. Gulliksen's formula 42, used to compute criterion variance in the Youth Population, requires such an entry. This criterion variance is essential for converting Beta-weights into b-weights and obviously cannot be directly computed in the Youth Population.

As previously stated, our objective is to have an algorithm replete with valid formulae that will convert operational test scores into LSEs of the criterion (i.e. PP composites) in a scale appropriate for use in the indicated population.

Application of Formulae 37 and 42

Applying combined formulae 37 and 42 to one criterion variable at a time, and making small changes in Gulliksen's notation, we can compute the squared SD of each Youth Population criterion variable associated with each job family. This result can be described as the Youth Population criterion variance, or YPCV:

$$YPCV = 1.0 + \underline{C}_{xc} \, (C_{xx})^{-1} \, (\, (\, {}^{*}C_{xx}) \, (C_{xx})^{-1} - I \,)(\, \underline{C}_{xc})^{T},$$

where ($\underline{C}_{xc}$) is a 9 by 1 vector of co-variances between the criterion variable and each of the 9 tests, C_{xx} is a 9 by 9 matrix of co-variances among 9 tests using the operational test scores, and vectors are denoted by underlining. Note that the asterisk matrix, e.g., *C, indicates computation in the unrestricted (i.e., Youth Population) sample.[22]

The R matrix has the following relationship with the C_{xx} matrix:

$$R = S_x \, C_{xx} \, S_x,$$

where S is a diagonal matrix for which the diagonal elements are equal to the reciprocals of the SDs of either the subtests or the criterion variable in either the MOS sample or the Youth Population, as indicated.

The ${}^{*}C_{xc}{}^{T}$ matrix is derived from the Gulliksen formula as:

$$({}^{*}C_{xc})^{T} = ({}^{*}C_{xx}) \, (G) = ({}^{*}C_{xx}) \, (C_{xx})^{-1} (C_{xc})^{T} \; .$$

---

[22] Note that YPCV can also be written as follows:

$$YPCV = 1.0 + (W^{T})({}^{*}C_{xx} \, W - (\underline{C}_{xc})^{T} \,),$$

where $W = (C_{xx})^{-1} \; (\underline{C}_{xc})^{T}$, a 9 by 1 vector of regression weights for a specified job family. W will also be recognized as one column of the G matrix.

Note that one column of $*C_{xc}^{T}$ is $(\underline{C}_{xc})^{T}$, a vector used in the computation of YPCV. The validity matrix ($*V^{T}$) required to compute Beta weights in the Youth Population has the following relationship with the $*\underline{C}_{xc}^{T}$ vector:

$$\text{one column of } *V^{T} \text{ is } (*S_x)(*\underline{C}_{xc})^{T}(*\underline{S}_c),$$

and note that $*\underline{S}_c$ is a scalar.

Positively Weighted Composites for the Visible Tier

This section extends the initially professed objectives of this appendix beyond restriction in range corrections and the conversion of Betas to u and k values. We will now discuss the methodology for selecting the "best" positively weighted composites where best is defined in terms of maximizing the multiple correlation coefficient of a set of tests with the criterion.

The surest way to find this best positively weighted composite from a set of n tests is to compute the Betas and validity coefficients for every possible combination of n tests, then successive levels: for n-1 tests, then n-2 tests, …to 2 tests --- rejecting any combination of tests that has one or more negative weights. There is no need to actually consider all of these combinations since there comes a point in this process where all multiple correlation coefficients (Rs) for succeeding levels are lower than the highest R in a prior level.

The multiple-correlation coefficient, R, corresponding to each set of Betas is computed for each combination whether or not all of the weights are positive. Clearly, if the R for each combination of m-1 tests, negative weights permitted, was less than the highest R for m positively weighted subtests computed from the combinations considered at the prior level, the stopping point has been reached. After the stopping criterion has been reached, the set of subtests with all positively weighted coefficients that provides the maximum R is selected as the very best set and these weights become the B-weights for the associated subtests. All other tests are given a weight of zero in the composite associated with the specified job family.